CEAMF STUDY, VOLUME 1

A CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) FOR NORTHEAST BRITISH COLUMBIA

FINAL

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PREPARED FOR: THE BC OIL AND GAS COMMISSION – THE MUSKWA-KECHIKA ADVISORY BOARD

A CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) FOR NORTHEAST BRITISH COLUMBIA

FINAL REPORT

Prepared for:
The BC Oil and Gas Commission
The Muskwa-Kechika Advisory Board

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Executive Summary

Report Design and History

What is the purpose of this report?	The purpose of this report is to describe a framework to both assess and manage cumulative effects in the study area. The product of this is referred to as a Cumulative Effects Assessment and Management Framework (CEAMF).
What is the study area?	The study area is the portion of northeast BC that is bordered by the Peace River to the south, the Muskwa-Kechika Management Area (MKMA) to the west, the Alberta provincial border to the east, and the NWT territorial border to the north.
Why was this report done?	This report was done as a response to concerns in the region about the possibility of worsening environmental effects due to multiple land and resource use activities. Some mechanism was needed to address these concerns; (specifically, those related to the potential contributions of oil and gas projects to the cumulative effects), and the Oil and Gas Commission's (OGC) process that reviews project applications.
Objectives of this Report	The objectives of the report are to: 1. define a CEAMF, describe its attributes, and explain how it may be implemented; 2. assist project reviewers, specifically the OGC, in addressing cumulative effects as part of their regulatory mandate; and 3. assist land and resource managers in addressing cumulative effects throughout the study area.
For whom was this report written?	This report was written for the OGC and the Muskwa-Kechika Advisory Board (MKAB).
For whom is the framework intended?	The framework is designed, principally, to meet the needs of the OGC. The framework is also intended to meet the needs of advisory and administrative bodies that are responsible for managing the MKMA; specifically, the MKAB and the provincial government. However, all or many aspects of the framework may also be adopted by government ministries that are responsible for lands outside of the MKMA, by First Nations, and by other organizations and public groups in the region.
Who funded this report?	The report was funded by the OGC's Environmental Fund, with partial contributing funding from the Muskwa-Kechika Trust Fund.
Who did the report?	Development and production of this volume of the study was led by AXYS Environmental Consulting Ltd., located in Sidney, BC. Other consultants contributed specific material within the report.
Who else has been consulted?	Team members have consulted with representatives of the OGC, MKAB, and various government ministries. Furthermore, a two-day workshop was held in Fort St. John in January 2002, in which the aforementioned representatives and First Nations were invited to discuss the proposed work.

How is this report organized?

This report represents Volume 1 of a two-volume set. Volume 1 *A Cumulative Effects Assessment and Management Framework (CEAMF) for Northeast British Columbia*, is organized into the following main sections:

- Introduction (describes the purpose, scope and context for the work);
- Land Administration (describes government land and resource use management in the region);
- Regional Assessment (describes the land use setting and the state of selected environmental features);
- Regional Framework (describes the framework); and
- Summary and Recommendations (outlines key finding, contributions to science and decision making, and a series of recommendations).

What are the other volumes in this report series?

There is one other volume in this series: Volume 2 *Cumulative Effects Indicators, Thresholds, and Case Studies*, which proposes cumulative effects indicators and thresholds for the region based on the detailed analysis of cumulative effects in two case study areas. Volumes 1 and 2 are interconnected, and each provides a specific contribution to the framework.

Report Discussion and Results

What are cumulative effects?

Cumulative effects are changes to the environment that are caused by an action in combination with other past, present, and future human actions. These changes are typically evaluated under some form of regulatory requirement for specific project applications through a Cumulative Effects Assessment (CEA).

What is a framework?

A Regional Cumulative Effects Assessment and Management Framework (CEAMF) is an administrative structure that combines various initiatives that assist decision makers in assessing and managing the effects of human use on the land.

What types of effects does the framework address?

The report focuses on cumulative effects on the natural environment; however, the framework may readily be expanded to include effects on wilderness values, First Nations traditional values, and other social, cultural, economic and land use issues.

What are the parts of the framework?

The framework comprises the following main parts:

- Regional assessment;
- Regional planning and research studies;
- Effects management;
- Project assessment matrices;
- Project screener;
- Thresholds; and
- Monitoring.

This are tied together by what is referred to here as the Sustainable Resource Management Strategy (SRMS), which is a CEAMF customized for Northeast BC.

What is the regional assessment?

The regional assessment is a characterization of the state of land and resource use and various environmental features (air quality, soils and terrain, aquatic resources, vegetation and wildlife) in the study area. A description of each environmental feature includes a discussion of issues, effects, valued components, and specific areas of possible concern (referred to as hot spots). The regional assessment provides, at a coarse scale over a large geographic area, information of use to both project-specific reviewers and regional planners. This section includes a series of 30 maps illustrating key concepts.

What are the regional planning and research studies?

The regional planning and research studies are various initiatives that improve and add to existing information that is useful and necessary to decision makers. These studies focus on applied landscape ecology, ecological response studies, future scenario forecasting, and effects monitoring.

What is effects management?

Effects management includes any measures needed to minimize or eliminate effects from human disturbances. These measures may be the responsibility of a single project proponent, of multiple project proponents, or of government. As such, these measures are either project-specific or regional in nature. The report describes 29 measures, and recognizes those already being implemented or considered in northeast BC and elsewhere.

What are the project assessment matrices?

The project assessment matrices provide generic and specific information that is useful in the review of individual oil and gas project applications. The information provided in the matrices is based on the five conventional steps in project assessment, including scoping, analysis, mitigation, significance evaluation, and follow-up.

What is the project screener?

The project screener is a step-by-step process for OGC staff to follow when reviewing project applications for possible cumulative effects issues. The process has two options: one is a simple series of questions that can readily be answered with available information; and the other is based on thresholds to be used when they become available. An expanded review process is also described for situations warranting more detailed review of an application as a result of certain environmental concerns. This OGC-customized screening tool is called the Application Cumulative Effects Screener, or ACES.

What are thresholds?

Thresholds are measures of limits of acceptable change. Four types of thresholds are proposed based on access density in broad landscapes, access density within watersheds, core habitat security, and species-specific thresholds. In the framework, contribution to the threshold by each project is compared to three levels of thresholds (cautionary, target, and critical). The thresholds are introduced and summarized in this report, and are fully detailed in Volume 2.

What is monitoring?

Monitoring is the on-going determination of environmental conditions, the verification of predicted effects, and the verification of the effectiveness of applied effects management measures. It is a critical aspect of the framework – one that is directly linked to the principles of adaptive management.

What is the fundamental approach on which the framework is based?

The framework is based on the following principles:

- a response to assessing and managing cumulative effects within a regulatory review process for individual project applications must not be onerous to the majority of applicants or to the reviewers;

- in the absence of thresholds, cumulative effects can only reasonably and practically be addressed through the implementation of measures that successfully reduce environmental effects. Some of these measures may be specific to individual projects, while others require joint coordination and involvement among the various parties involved. The result of these efforts is to slow down the pace of negative environmental change, not necessarily to eliminate cumulative effects;
- cumulative effects, ultimately, can only be managed through the implementation of thresholds. The collective contributions of human activities are compared to thresholds, which if exceeded, result in adjustments to projects, implementation of regional initiatives, and possibly, the temporary or indefinite rejection of projects;
- with or without thresholds, various regional initiatives should be implemented that provide the necessary information to land and resource managers to assist their decision-making. These initiatives may be supported either by government or jointly with industry; and
- in recognition of the above, a 'dual-track' approach is proposed that includes addressing cumulative effects at the project level while at the same time addressing cumulative effects at the regional level.

How would the framework be implemented?

The framework is practically implemented in a process referred to as the Sustainable Resource Management Strategy (SRMS). Based on the 'dual-track' approach, it includes parts that are immediately implementable and some parts that may be incorporated as administrative resources, information, and financial support become available. The SRMS introduces the concept of a Steering Committee to advise on regional initiatives and to assist in the review of contentious project applications. A regional database of information is also introduced as part of the SRMS, based on the lead of the Regional Assessment in this report, and on existing provincial data sources.

Who would be involved in the implementation?

The report describes the roles and responsibilities of government, land and resource managers and planners, regulatory reviewers, project proponents, the proposed Steering Committee, the MKAB, the Oil and Gas Advisory Committee, First Nations, the public, and non-government organizations.

How would thresholds be implemented?

In Volume 2, thresholds were developed and demonstrated within two case study areas, one being a sub-set of this report's study area. To implement these thresholds broadly throughout northeast BC, initiation of a pilot program is recommended. The program would be used to demonstrate practical application of thresholds within a regulatory review and provincial planning process. Following a successful pilot, thresholds would be incorporated within the OGC's and other review processes.

Are there priorities for implementation of the framework?

It is expected that the OGC and MKAB, in consultation with other ministries and stakeholders, and in consideration of available resources and current priorities, would determine which of this report's recommendations they have the capacity to immediately implement. Notwithstanding this expectation, four of the recommendations are key: adopting a 'dual-track' approach to assessing and managing cumulative effects; creating a SRMS Steering Committee; maintaining a regional database; and implementing ACES.

Does the framework solve all cumulative effects problems?

Theoretically, implementation of any framework would solve all cumulative effects problems, as by definition a framework is an all-encompassing approach to addressing cumulative effects through the use of a complete and inter-related set of initiatives. In practice, however, any framework is subject to various real-world limitations that are common to matters affecting regulatory process, public land administration, and industry and public interest. As such, the framework, as proposed in this report in the form of the SRMS, recognizes a phased and modular approach (i.e., users of the framework select appropriate initiatives over time, as required), and the need for time and broad participation to develop the various initiatives as described. Only in this way can a framework be accommodating, rather than intrusive.

Where does the framework start and end?

The framework, as described in this report, is a beginning, that with the involvement and support of the various parties recognized, would assist decision-makers in best fulfilling their mandates, and assisting the public and industry in becoming effectively involved in the decision-making process. With the incorporation of monitoring and adaptive, on-going evaluation of framework objectives and procedures, the framework can continually evolve to meet the mandate of government, and the interests of northern BC communities and resource users.

Contributions to Science and Decision-making

Overall, what does the framework contribute to science and decision-making?

Although other regions have attempted to develop and implement frameworks for addressing cumulative effects, the proposed SRMS for northeast BC is unique in comparison to many other frameworks as listed below.

- It could be immediately and practically applied as it builds on existing tools and requires limited changes to the current administrative and management structures in place for the region (the only change being the addition of the proposed SRMS Steering Committee).
- It recognizes and is consistent with both local and strategic level planning for the region and its implementation does not require that land use objectives be re-visited in the short term – it provides a 'bridge' between various levels of planning and on-the-ground project operations.
- It builds on and supports scientific research and provides a mechanism (in the form of the regional, publicly-accessible database) that can be used to continually update the state of knowledge for the region and feed that information back into decision-making processes.
- While focused on the environmental effects of oil and gas activities, the concepts presented here are readily adaptable for use by other land management agencies and for use in the assessment and management of social, cultural, recreational and economic effects.
- It provides realistic options for assessing, managing, and mitigating cumulative effects resulting from oil and gas activities, at both the local and regional scale, based on knowledge of what is appropriate to the region and what has been proven successful elsewhere.

- It breaks new ground in its identification of scientifically-based indicators and thresholds, which are customized for use in the region to which they would be applied, and which are implementable at a pilot scale in the short term (in conjunction with the recommended project screener).
- It recommends a workable and non-onerous approach to incorporating cumulative effects into the day-to-day application review procedures currently in place by the OGC, while requiring only minimal changes to those procedures for the majority of application reviews;
- It relies not on one management agency to solve the problems of cumulative effects but rather provides an 'umbrella' under which all cumulative effects management decisions could be made, by any agency or organisation, at any time – the concept of a multi-sector steering committee devoted to addressing cumulative effects issues is unique within the region.
- In generally, it provides reference points, guidance and options which support decision-making, which are adaptable to a variety of situations, and which are linked to other planning and management processes at the local, sub-regional, and regional scales.

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Volumes

Volume 1:	A Cumulative Effects Assessment and Management Framework (CEAMF) for Northeast British Columbia
Volume 2:	Cumulative Effects Indicators, Thresholds, and Case Studies

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List of Abbreviations

AAC	Annual Allowable Cut
ACES	Application Cumulative Effects Screener
ALCES	A Landscape Cumulative Effects Simulator
ALR	Agricultural Land Reserve
AMA	Access Management Area
ATV	All-terrain Vehicle
AXYS	AXYS Environmental Consulting Ltd.
BC	British Columbia
BCEAA	BC Environmental Assessment Act
BEC	Biogeoclimatic Classification
BEI	Broad Ecosystem Inventory
BEU	Broad Ecosystem Unit
BPPTP	Besa-Prophet Pre-Tenure Plan
BTM	Baseline Thematic Mapping
BWBS	Boreal White and Black Spruce
CAD	Conservation Area Design
CAPP	Canadian Association of Petroleum Producers
CCME	Canadian Council of Ministers of Environment
CEA	Cumulative Effects Assessment
CEAA	Canadian Environmental Assessment Act
CEAMF	Cumulative Effects Assessment and Management Framework
CEC	Cation Exchange Capacity
CEMA	Cumulative Effects Management Association
CWS	Canadian Wildlife Service
DEM	Digital Elevation Model
DFO	Fisheries and Oceans Canada
DIAND	Department of Indian Affairs and Northern Development (Federal)
DOE	Department of the Environment (Federal)
EEP	Environmental Protection Plan
EFP	Environmental Field Report
EFR	Environmental Field Report
EIA	Environmental Impact Assessment
ELC	Ecological Land Classification
EMM	Effects Management Measures
ER	Ecological Reserve
ERDZ	Enhanced Resource Development Zone
ESSF	Engelman Spruce- Subalpine Fir
EUB	Energy and Utility Board

FRBC	Forest Renewal BC
GDP	General Development Permit
GIS	Geographic Information System
GLOBIO	Global Methodology for Mapping Human Impacts on the Biosphere
GOAT	GIS Oracle Access Tool
IL	Information Letter
ILM	Integrated Landscape Management
IMP	Integrity Management Plan
LIS	Low Impact Seismic
LRMP	Land and Resource Management Plan
LWBC	Land and Water BC Inc.
MDRC	Maximum Dissturbance Review Criteria
MEM	Ministry of Energy and [illegible]nes
MKAB	Muskwa-Kechika Advisory Board
MKMA	Muskwa-Kechika Management Area
MOE	Ministry of Environment
MOF	Ministry of Forests
MSRM	Ministry of Sustainable Resource Management
MWLAP	Ministry of Water, Land and Air Protection
NEB	National Energy Board
NES	Northern East Slopes
Nox	Nitrous Oxides
NWT	Northwest Territories
OGC	Oil and Gas Commission
PAI	Potential Acid Input
PAS	Protected Areas Strategy
PM	Particulate Matter
PTP	Pre-tenure Plans
RDP	Resource Development Permit
RLUP	Regional Land Use Plan
RMZ	Resource Management Zone
RoW	Right-of-Way
SMZ	Special Management Zone
SOE	State of the Environment
SO_x	Sulphur Oxides
SRMP	Sustainable Resource Management Plan
SRMS	Sustainable Resource Management Strategy
SWB	Spruce-Willow-Birch
TCU	True Colours Unit
TEK	Traditional Ecological Knowledge (or Indigenous Knowledge)
TIS	Threshold Implementation Strategy

TP	Total Phosphorous
TRIM	Terrain Resource Inventory Mapping
TSA	Timber Supply Area
UNBC	University of Northern British Columbia
USEPA	United States Environmental Protection Agency
VEC	Valued Ecosystem Component
VSC	Valued Social Component
WMA	Wildlife Management Area
ZOI	Zone of Influence

CHAPTER 1: INTRODUCTION

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY

1 Introduction

1.1 Background

As part of the British Columbia (BC) Oil and Gas Commission's (OGC) initiative to address environmental effects associated with oil and gas development, an environmental fund was established in 1998 to support research projects over a five-year period. During 2001, three research areas were considered: air emissions; cumulative effects; and ecosystem health and integrity. With regard to cumulative effects, AXYS Environmental Consulting Ltd., Diversified Environmental Services, and Salmo Consulting Inc. proposed to develop a Cumulative Effects Assessment and Management Framework (CEAMF) for northeast British Columbia, including the Muskwa-Kechika Management Area (MKMA). The proposal was accepted by the OGC, and complementary funding was provided through the Muskwa-Kechika Trust Fund, a fund created through the *Muskwa-Kechika Management Area Act* to promote research aimed at addressing ecological sustainability and maintenance of wilderness characteristics in the MKMA by providing information to support planning processes.

Cumulative effects are changes to the environment that are caused by an action in combination with other past, present, and future human actions (Hegmann *et al.* 1999). These environmental changes are typically evaluated under some form of regulatory requirement for specific project applications through a Cumulative Effects Assessment (CEA). CEAs build on what has been learned and applied in Environmental Impact Assessments (EIA); however, CEAs display some marked differences to EIAs that must be clearly understood by assessment practitioners and project proponents. To achieve the overall objective of mitigating and addressing environmental effects of oil and gas activities, it is necessary to have agreed-upon standards and guidelines for assessing and managing the cumulative impacts of these activities – i.e., a 'framework' (defined in more detail in Section 1.4).

The CEAMF presented in this report describes a practical approach, specific to northeast BC, for assessing and managing project-specific and regional cumulative effects. The framework includes and is supported by a database of regional information and a baseline assessment that identifies cumulative effects issues and 'hot spots' in the region. The framework also provides direction for other research on cumulative effects that will be undertaken under the OGC Environmental Fund or the Muskwa-Kechika Trust Fund, or by academia and industry. Finally, the framework provides an 'umbrella' under which environmental and cumulative effects assessment and management tools (e.g., application screening, modelling, land use planning, etc.) can be employed and updated.

The CEAMF is the overarching component of a broader body of work that will assist the OGC and Muskwa-Kechika Advisory Board (MKAB) in proactively addressing land use and resource management issues in northeast BC. The key elements of the CEAMF, including the regional assessment and a proposed application screening tool, are described in detail in this volume (Volume 1). Cumulative effects indicators, thresholds, and case studies are described in Volume 2.

While the proposed framework focuses on cumulative effects associated with oil and gas activities, and what can be done by the OGC to assess and manage such effects, it is recognized that you cannot manage cumulative effects for one sector in isolation of other influences. In the case of northeast BC, various land use activities will potentially contribute to cumulative effects. These activities include, but are not limited to, forestry, mining, hunting, trapping, fishing, hydroelectric development, transportation and utility development, agriculture, recreation, and human settlement. As a result, although the recommendations presented in both volumes of this study are aimed at the OGC and MKAB, specific components of the framework rely heavily on the involvement of other ministries, First Nations, industry, and stakeholders.

The development of a CEAMF for northeast BC is an ambitious and complex undertaking requiring broad-level support from regulators, resource users, and other stakeholders. To ensure that the CEAMF meets the needs of the OGC, the MKAB, and other stakeholders in northeast BC, input was received from government ministries, First Nations, the oil and gas industry, non-government organizations, and other interest groups through a series of meetings, workshops, and presentations. The CEAMF also recognizes and builds upon other planning activities in the region, including Land and Resource Management Plans (LRMPs), Sustainable Resource Management Plans (SRMP), local-level plans, and other initiatives that set land management objectives. As such, it provides a 'bridge' between regional-scale land planning and management and site-specific (i.e., project-level) activities.

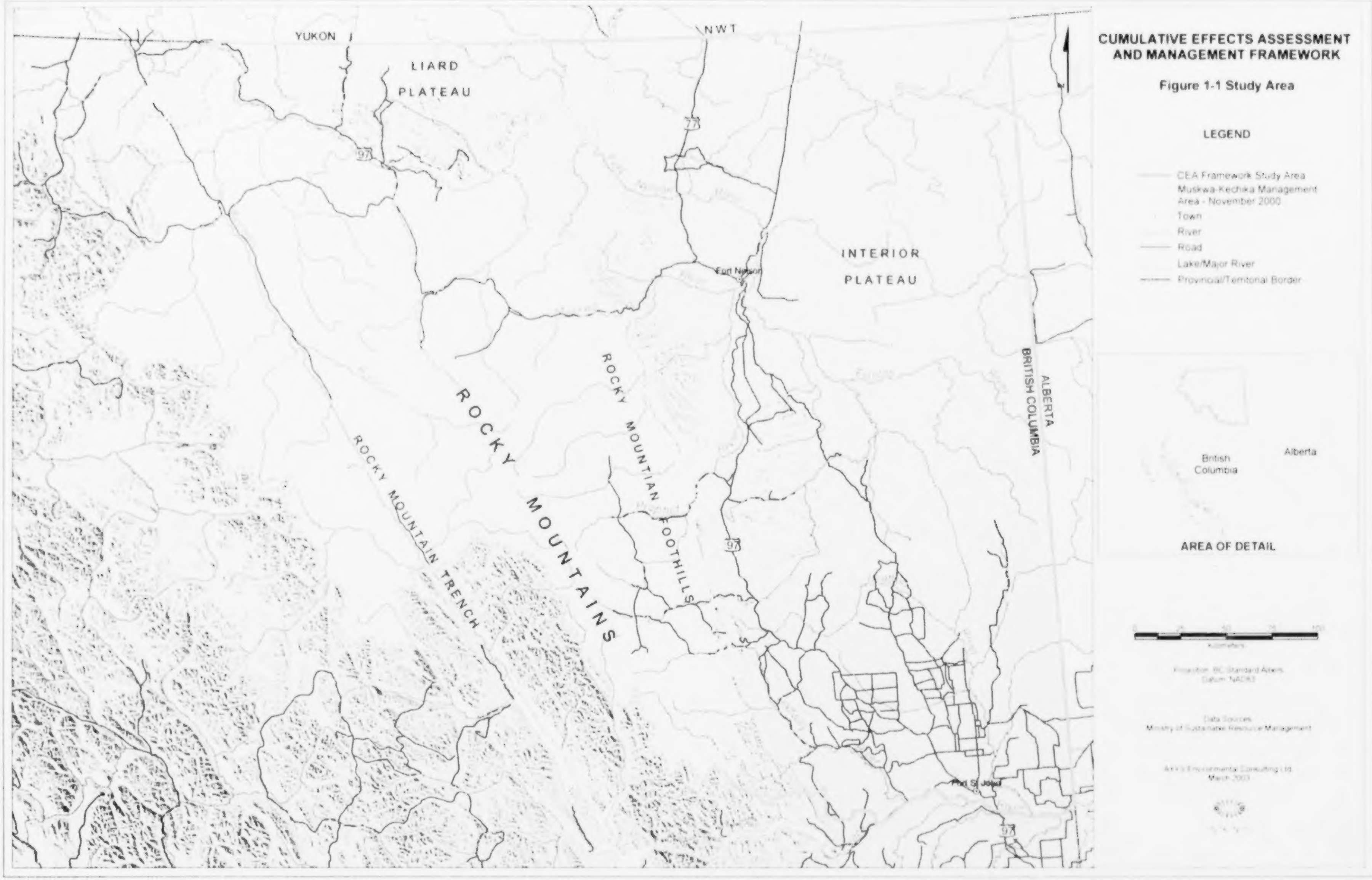
1.2 Study Area

The CEAMF and baseline regional assessment presented in this report are specific to the northeast British Columbia region (Figure 1-1). The study area includes the Fort Nelson and Fort St. John Forest Districts, a portion of the Mackenzie Forest District, and the whole of the Muskwa-Kechika Management Area (MKMA). The study area covers approximately 16.4 million hectares.

The Fort Nelson, Fort St. John and Mackenzie LRMPs guide land use activities in the study area (see also Section 2.3). Sixty per cent of the study area falls within the Fort Nelson LRMP area, 28.5% falls within the Fort St. John LRMP area, and 11.5% falls within the Mackenzie LRMP area. About 9% of the study area is classified as protected area, and is managed as part of the BC Protected Areas System.

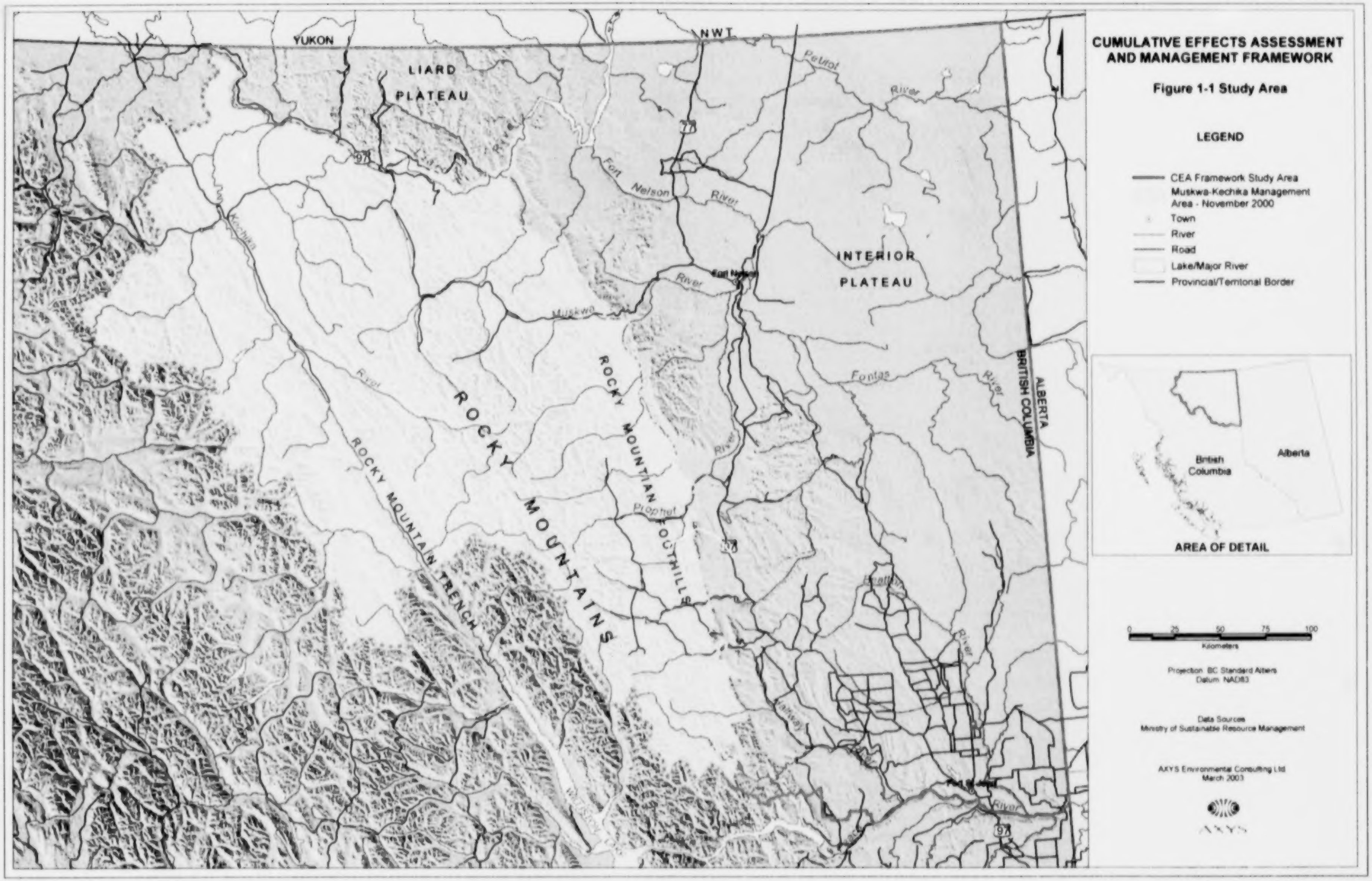
The MKMA covers approximately 6.3 million hectares of the study area, and encompasses the eastern foothills of the Muskwa range of the Rocky Mountains (north of the Peace River), the Kechika range of the Cassiar Mountains, and the northern portion of the northern Rocky Mountain Trench. The MKMA comprises one of the largest remnants of untouched wilderness in North America, south of 60° latitude. As such, it provides critical habitat and movement corridors for an abundant and diverse group of large mammals, and supports the continent's largest intact predator-prey system (Gailus 2000). Although the MKMA contains numerous provincial parks and protected areas, it is neither a park nor an ecological reserve.

Figure 1-1. Study Area



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 1-1 Study Area



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 1-1 Study Area

The MKMA is a unique management concept, envisioned and designed as a special management area that will allow resource development to continue while the principles of conservation biology are applied to protect important wildlife and wilderness values. Within the MKMA, 11 protected areas have been established where resource extraction activities are not permitted. These core protected areas are connected by transition areas and buffer zones that allow for a number of sustainable human activities. Elsewhere in the MKMA, extractive resource development is permitted where it is consistent with local level plans and zoning[1] (e.g., pre-tenure plans and wildlife management plans – see also Section 2.4.2).

Northeast BC contains some of the richest oil and gas reserves in the province. In recent years, total oil and gas revenues have exceeded $200 million annually, and permanent employment in the oil and gas sector has accounted for almost 20% of the local economy (Gailus 2000). Other industries important to the region's economy include forestry, mining of metallic and non-metallic resources, tourism, and localized agriculture.

The rapid rate of growth of oil and gas exploration and development in northeast BC has raised concerns about cumulative impacts from oil and gas-related activities alone, and in combination with other land uses. Further, the region, and the MKMA in particular, contains considerable non-industry values such as wilderness, public and commercial recreation, hunting, trapping, fishing, and First Nations' traditional and cultural values. Thus, this area is a good candidate for the development of a regional CEAMF.

Land use and administration in the study area are discussed in more detail in Section 2.

1.3 Objectives

The principal objective of Volume 1 is to present a CEAMF for conducting single-project assessments and managing regional cumulative effects in northeast BC. This objective will be achieved by:

- identifying preferred tools and approaches for cumulative effects assessment and management at the project-specific (i.e., local) and regional levels. This will help the OGC, proponents, and other stakeholders to better understand cumulative effects and to develop and implement methods to minimize these effects before they occur;
- initiating the development of a regional, spatially-referenced database and map series which contain information on biophysical attributes and development disturbances. The database and maps provide an overview of existing cumulative effects in the region so that potential areas of concern (i.e., hot spots) can be identified and significant data gaps noted. This will support project-specific assessments and will aid in applying proactive effects management; and

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[1] For example, Special Wildland Zones are included in the Mackenzie LRMP portion of the MKMA. In these zones, forestry is excluded by other development activities are permitted.

- guiding future research priorities by identifying important data gaps regarding analytical methods, mitigation activities, and significance determinations. This will help with incorporating results from other research projects into practical applications for analyzing, evaluating, and managing cumulative effects (e.g., the development of new mitigation measures).

The framework can eventually be used by the OGC and industry as:

- a baseline for future assessments;
- a means of flagging regional hot spots and areas that require management or remedial action;
- a project screening tool to aid in the review of future applications and management initiatives;
- a guide to available effects assessment and management tools;
- a practical application for incorporating results from other research projects; and
- a means of identifying important data gaps and setting priorities for follow-up and monitoring.

Although the CEAMF was developed for the OGC and MKAB, it will have direct application to, and broad implications for, the oil and gas industry in the region. The CEAMF will aid the industry by raising awareness of cumulative impacts; providing increased understanding of how CEAs can be conducted as part of standard EIA processes; presenting a means for the consistent application of CEA methods; and providing greater consideration of cumulative effects and mitigation measures as part of oil and gas activities in the region.

While the proposed CEAMF presently focuses on assessing and managing cumulative effects relating to oil and gas activities, the framework has been developed with future expansion in mind. For example, the framework can be adapted to address other industrial impacts (e.g., forestry and mining), as well as non-industrial values (e.g., wilderness recreation). This future expansion of the framework will be particularly important within the context of the MKMA, in which only a small portion of the area has high oil and gas potential.

The Terms of Reference for this project are provided in Appendix A.

1.4 Definition of a Framework

Traditionally, cumulative effects have been assessed and managed on a project-by-project basis. Cumulative effects, however, can also be assessed and managed on a regional basis through a jointly coordinated and jointly funded approach that involves governments, proponents, and the public. A regional CEAMF is an administrative structure that can help decision makers assess and manage the effects of human use of the land.

A CEAMF, typically, is developed when concerns are raised about the long-term environmental effects of many land uses over a large geographic region (usually defined by jurisdictional, ecological, physiographic, or resource borders). This is especially true for relatively undisturbed areas facing rapid and extensive resource development from known and potential future projects.

A CEAMF is useful because it provides a 'one-window' approach to addressing cumulative effects over large geographic areas. As such, the various elements of the framework (discussed below) are coordinated to complement each other, and to ensure that effects of concern are identified, addressed, and monitored. Information on environmental and land use conditions is shared, stakeholders become involved, and a useful product is developed that can be used either to assist in the review of individual project applications, or to understand longer-term trends at a regional scale. Without a coordinated approach, information would likely remain unavailable or would not focus on regional issues of greatest concern. Project proponents, regulatory reviewers, and land administrators would likely be hampered by inadequate information, and would continue to make decisions in isolation.

A CEAMF, therefore, ties together the various initiatives that individually or collectively provide the information on which decisions are based. The CEAMF may also provide a means of interpreting information that will help land managers answer fundamental questions such as:

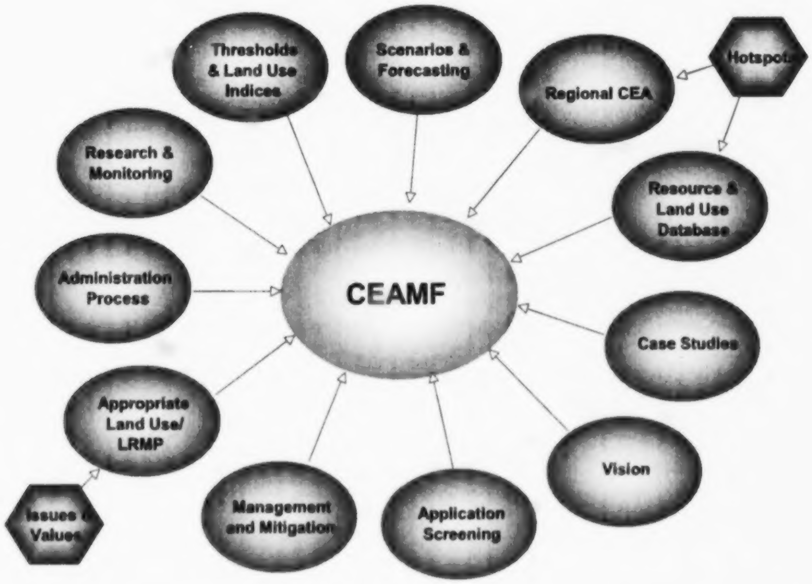
- Could a single proposed project cause a problem? If so, what can be done to mitigate that problem?
- Is there an environmental problem now as the result of many human disturbances? If so, what can be done to mitigate that problem?
- Could there be an environmental problem sometime in the future? If so, how soon, and what can be done to avoid that problem?

A CEAMF may include any combination of the following basic elements (Figure 1-2):

- ecological monitoring (e.g., of water quality; movements of far-ranging species);
- ecological research (e.g., on species responses to human disturbances);
- assessment methods (e.g., for quantitative assessment of sediment loading on streams);
- administrative review process (e.g., incorporating information for consideration during review of project applications);
- administrative coordination (e.g., a central body to coordinate information and initiatives relevant to cumulative effects);
- mechanisms of administrative compliance (e.g., enforcement or voluntary compliance);

- databases and mapping (e.g., mapping of existing ecological features through use of a Geographic Information System (GIS));
- land use plans (e.g., zonation of a region to various levels of allowable land use);
- protected area planning (e.g., exclusion of human disturbances from certain areas);
- management techniques (e.g., definition of best practices for mitigating industrial projects; identification of opportunities for regionally coordinated mitigation);
- stakeholder consultations (e.g., ongoing involvement of affected communities);
- scoping (e.g., establishment of a vision for desired land use; identification of issues of concern, or environmental and land use features of importance);
- limits to growth (e.g., identification of ecological and land use thresholds);
- application review (e.g., implementation of a project application screening process);
- future scenario forecasting (e.g., predicted effects for different levels of future development);
- project-specific cumulative effects assessments (i.e., assessment of the contribution of a specific project to overall cumulative effects); and
- regional cumulative effects assessment (i.e., assessment of the effects of all land uses).

Figure 1-2. Elements of a CEAMF



- databases and mapping (e.g., mapping of existing ecological features through use of a Geographic Information System (GIS));
- land use plans (e.g., zonation of a region to various levels of allowable land use);
- protected area planning (e.g., exclusion of human disturbances from certain areas);
- management techniques (e.g., definition of best practices for mitigating industrial projects; identification of opportunities for regionally coordinated mitigation);
- stakeholder consultations (e.g., ongoing involvement of affected communities);
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- application review (e.g., implementation of a project application screening process);
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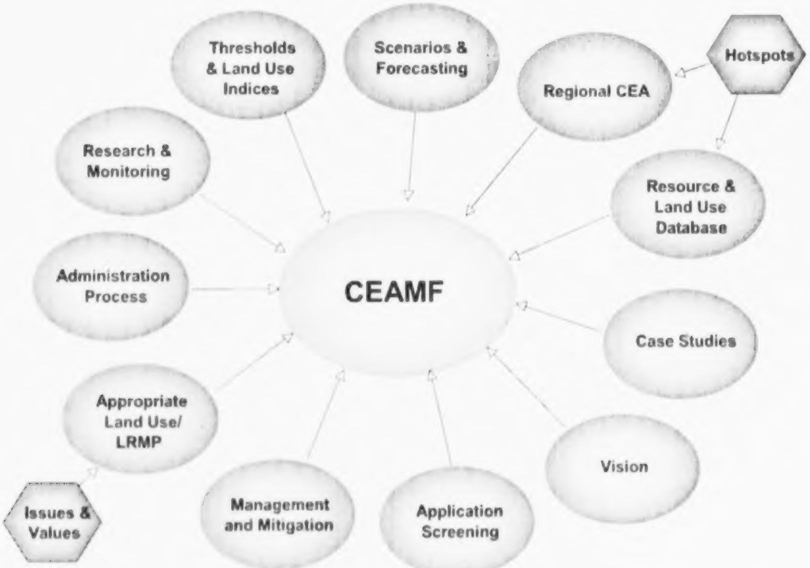
Figure 1-2. Elements of a CEAMF



Typically, a jointly-funded, independent group of government, industry, non-government, and First Nations representatives is formed and called upon to define issues of concern (e.g., increased hunting pressure due to increased access; degraded air and water quality; loss of wildlife habitat), and to identify initiatives that may be implemented to solve those problems. These initiatives are then incorporated into the CEAMF.

Usually, the next step involves collecting and mapping information that describes existing conditions. This is normally based on the monitoring of certain ecological indicators. The results are then used to identify priority areas that require management of existing and potential future effects. Individual projects submitted to authorities for approval may then be reviewed in the context of the CEAMF. Land use planners and other decision-makers may then develop policies or other administrative mechanisms to manage land use so as to best meet identified objectives. Finally, and over time, new information and data are added to the CEAMF so that decisions can be made in an adaptive management fashion.

Many of these components and steps are described in more detail and with specific reference to northeast BC in subsequent sections of this report. Cumulative effects frameworks in place in other areas are described in Appendix B.

1.5 Associated Project Components

This project includes a number of separate but integrated components (described below), which, when combined, will provide an approach for identifying, scoping, assessing, and managing cumulative effects in northeast BC. This approach will help the OGC and industry ensure that cumulative effects are addressed in the project approval process. It will also provide a basis for which the MKAB, First Nations, and stakeholders can participate in and monitor progress towards managing regional cumulative effects.

1.5.1 Cumulative Effects Assessment and Management Framework

This report (Volume 1) describes an overall approach, specific to northeast BC, for conducting project-specific assessments and for managing cumulative effects on a regional scale. Volume 1 describes:

- land use setting and planning context in northeast BC;
- identification of important regional issues;
- selection of indicators for assessing ecosystem and socio-economic effects (i.e., Valued Ecosystem Components (VEC) and Valued Social Components (VSC));
- identification of hot spots or areas of potential concerns for specific VECs or VSCs;
- a dual-track approach (project-specific or regional) for addressing cumulative effects;
- effects management measures (e.g., thresholds, modelling, coordinated land planning); and
- recommendations for implementing the CEAMF and its components, including roles and responsibilities of key players.

1.5.2 Project Screener

Imbedding within the CEAMF are recommendations to implement an OGC Application Cumulative Effects Screener (ACES), a key component of the overall CEAMF. Section 4.2.3 of Volume 1 outlines the development and testing of an application screening process to assist the OGC in making decisions on petroleum exploration, development, and production proposals, and in managing cumulative effects. The screener provides a systematic method for reviewing project applications, and allows for consistent and accountable decision-making. The screener is designed to fit within the existing OGC application review process. Implementation of the screener would require processes for establishing, managing, and updating regional databases, as well as staff training, all of which are discussed in Section 4.2.3.

1.5.3 Indicators, Thresholds and Case Studies

Volume 2: Indicators, Thresholds and Case Studies describes candidate cumulative effects thresholds and a scheme for implementing those thresholds. Candidate thresholds are based on a literature review and specific evaluations of cumulative effects on fish and wildlife in two representative areas of northeast British Columbia. The case studies test and develop approaches for assessing and managing cumulative effects on fish and wildlife resources, and evaluate the suitability of available data. Volume 2 includes:

- a literature review on appropriate ecological indicators and thresholds for fish and wildlife management;
- a spatial database of existing biophysical and land use features for each representative area;
- a review of development and renewable resource trends for each representative area;
- the application of various methods and indicators to assess cumulative effects;
- the identification of candidate thresholds for northeast British Columbia;
- recommendations on the use of these thresholds for cumulative effects assessment and management; and
- the identification of implementation and data needs.

1.6 Use and Structure of the Report

This report should be used as a guide for assessing and managing cumulative effects at the project-specific and regional scales. The main audience for the CEAMF is the OGC; however, this report will also be of interest to other land management agencies, the MKAB, First Nations, proponents of industrial activities, residents of local communities, and other stakeholders.

This report consists of the following sections:

- **Section 1: Introduction** – provides a background to the history and structure of the report, defines the meaning of Cumulative Effects Assessment and Management Framework, and introduces the companion parts of the framework;
- **Section 2: Land Administration** – describes the administrative context for land management in British Columbia, and the study area, specifically;
- **Section 3: Regional Assessment** – describes the development of a database of environmental and land use information for the study area, summarizes existing environmental and land use features, identifies cumulative effects issues, and provides examples of how the database can be used to identify potential cumulative effects hot spots;
- **Section 4: Regional Framework** – describes a process for assessing and managing cumulative effects at the project-specific and regional level, and presents an approach for implementing the CEAMF, including respective roles and responsibilities of various players;
- **Section 5: Summary and Recommendations** – presents a set of broad recommendations for using the CEAMF and integrating it with existing plans and tools, and for monitoring and managing cumulative effects; and
- **Section 6: References** – documents information sources used during the preparation of the report.

Volume 1 also includes a number of appendices that provide background and technical information on the CEAMF and its components.

1.7 Evolving Nature of the CEAMF

The CEAMF presented in this Volume has evolved using input from various stakeholders. Consultations took place at interim stages of the project. In August 2002, a series of meetings with government ministry staff were held in Fort St. John. These meetings provided opportunities for discussing ministry-specific issues and matters of regional cumulative effects management that are outside the jurisdiction of any one ministry. In October 2002, a presentation was made to the MKAB in Mackenzie. The purpose of the presentation was to update board members on progress in the development of the CEAMF, and to seek feedback on the framework and its use.

During the project scoping stage, a two-day workshop was held in Fort St. John, at the end of January 2002. The workshop was attended by representatives from government ministries, industry, First Nations, academia, and non-government organizations, and was used to introduce the project and the concept of the CEAMF. Preliminary issues, valued ecosystem and social components, and methodologies for deriving environmental and land use hot spots were presented. A summary of this workshop is provided in Appendix C.

Preceding the workshop, a one-day facilitated session was held with First Nations groups, which have traditional territories in northeast BC. The purpose of the session was to identify cumulative effects issues associated with First Nations use of the land, and to discuss referrals to First Nations regarding project applications for proposed oil and gas development.

It is fully anticipated that this work will continue to evolve, especially through implementation of the CEAMF and its components. Ultimately, Volume 1 does not represent the final solution to cumulative effect management. Rather, it presents a framework within which various effects assessment and management strategies may coexist in a complementary and adaptive manner. To be effective, the CEAMF should have the support of all stakeholders who have an interest in managing cumulative effects in the region.

CHAPTER 2: LAND ADMINISTRATION

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY

2 Land Administration

2.1 Regulatory Framework for Land Management

2.1.1 Roles and Responsibilities

The regulatory environment in British Columbia is complex. Provincial legislation related to administration of the land base includes, but is not limited to, the *Land Act, Water Act, Oil and Gas Commission Act, Forest and Range Practices Act, Wildlife Act, Heritage Conservation Act,* and the *British Columbia Environmental Assessment Act* (see Section 2.2). Pertinent federal legislation includes the *Fisheries Act, Waste Management Act,* and *Canadian Environmental Assessment Act* (see Section 2.2), among others.

Several provincial government ministries are responsible for management of Crown land. The Ministry of Sustainable Resource Management (MSRM) takes a coordinating role in land management, and is directly responsible for regional and sub-regional scale land and resource management planning, and finer scale sustainable resource management planning. The Ministry of Water, Land and Air Protection (MWLAP) is responsible for managing water, air, and wildlife habitat (although the permitting of water use is the responsibility of Land and Water BC Inc.). Provincial parks are administered under the Protected Areas Branch of MWLAP's Environmental Stewardship Division.

Land and Water BC Inc. is responsible for issuing tenures (including leases and licenses of occupation) for the use of Crown land for activities other than those related to oil and gas exploration or development. The Ministry of Forests (MOF) is responsible for forest tenure administration, determination of Annual Allowable Cuts (AAC), forest planning, and the management of timber harvesting, grazing, and recreational uses occurring on forest land. Land administration objectives used to manage forests in BC must also comply with the *Forest and Range Practices Act* (Government of BC 2002).

Throughout the province, oil and gas activities are regulated through the BC Oil and Gas Commission (OGC). Oil and gas pre-tenure planning is currently occurring in the MKMA[1]. The pre-tenure planning process (discussed further in Section 2.4.2) is being led by MSRM but involves various other regulatory agencies including the Ministry of Energy and Mines (MEM), MWLAP, and MOF as well as industry and other stakeholders.

2.1.2 Oil and Gas Commission

The Oil and Gas Commission is a regulatory agency that reports to the Minister of Energy and Mines. The OGC is responsible for overseeing oil and gas operations including exploration, development, reclamation, and pipeline transportation. The OGC regulates all oil and gas activity in BC by operating under a number of acts, including the

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[1] At present, pre-tenure planning is only a legislative requirement in the MKMA and the plans apply only to oil and gas tenures.

Oil and Gas Commission Act, *Petroleum and Natural Gas Act*, *Pipeline Act*, and all acts that govern the provincial land base in BC (OGC 2002a). Recent changes to the *Oil and Gas Commission Act* and the *Petroleum and Natural Gas Act* have resulted in greater streamlining of the permitting and application review process, which is intended to reduce the regulatory burden on clients and stakeholders (OGC 2002a). Some of these changes include the elimination of pipeline and access road questionnaires, duplicated information in the Operations Engineering Technical Review package for pipeline and facility applications, and of unnecessary information on Crown land applications and campsite questionnaires (OGC 2002a).

A recent addition to the responsibilities of the OGC is the creation of the General Development Permit (GDP). This may provide a means of managing cumulative impacts since a company must now submit an application based on the entire development plan. Previously, each proposed activity (e.g., well, road, pipeline) was reviewed as a stand-alone application, and project effects were assessed for separate activities. Other changes include the transferring of responsibilities and authorities under the *Waste Management Act* and the *Water Act* to the OGC, enabling provisions of the *Forest and Range Practices Act* to be enforced by the OGC, and establishing requirements for wells and test holes on private land (OGC 2002a).

In addition to reviewing project applications (see Section 4.2.2), the OGC requires companies to abide by certain standards and regulations. For example, companies are expected to complete an Integrity Management Plan (IMP) to ensure pipelines are safe from both a human health and an environmental perspective (OGC 2002b). Additionally, the OGC has specific guidelines for wells, well access, borrow pits, remote sumps, campsites, decking sites, pipelines, permanent access, stream crossings, and water removal (OGC 2002b). Guidelines for minimum construction setbacks have been established for specific fish and wildlife habitat values such as nesting sites, mineral licks, bear dens, beaver dams, and bull trout streams (OGC 2002c).

The OGC also operates under the following three fundamental standards:

- an open, accountable, and neutral process for assessing the environmental, economic, social, heritage, and health effects of projects;
- a co-operative review procedure with federal authorities; and
- meaningful participation by the public, proponents, First Nations, local governments, provincial, and federal agencies.

The OGC involves stakeholders in the regulatory process through the use of guidelines that require proponents to complete a consultation/notification process prior to submitting an application (OGC 2001). Additionally, the OGC has recently developed an application review process that will allow First Nations to review applications for potential infringement of Treaty rights (OGC 2002b).

2.2 Regulatory Requirements for Cumulative Effects Assessment

The *BC Environmental Assessment Act* (BCEAA) requires an assessment of environmental effects for all major provincial projects. The intent of the Act is to identify any foreseeable adverse impacts throughout the life of a project (including construction, start up, operation, and shut-down), and to determine ways to eliminate, minimize, mitigate, or compensate those impacts (Government of BC 2001). The Act, reformed in the spring of 2002 through Bill 38, forms a single review procedure for environmental assessments of projects that are subject to the Act. The purpose of Bill 38 was to provide greater flexibility in customizing review procedures on a project-by-project basis. This increased flexibility is intended to contribute to the government's strategic priorities for improving the investment climate in BC while preserving high environmental standards (Environmental Assessment Office 2002). Some specific changes to the Act that may have consequences for how EIAs are conducted in BC include the waiving of EIAs for projects that do not raise strategic impact concerns, and providing Ministers with the ability to make early decisions to terminate a review and reject a project where it is clear that the project does not satisfy government requirements.

The National Energy Board (NEB) is a federal agency that requires an assessment of environmental effects on all major federal projects. Projects within northeast BC that would require an assessment include inter-provincial pipelines or powerlines (NEB 2001). The NEB operates under the *National Energy Board Act* and has responsibility for applying related regulations, rules, guidelines, guidance notes, and memoranda of guidance (NEB 2001). For example, Section 28.2 of the *National Energy Board Act* directs oil and gas interests to adhere to Section 28 of the *Canada Petroleum Resources Act*, which states that the NEB may revoke a permit for a claimed "significant discovery" if further drilling proves it to be not significant.

The *Canadian Environmental Assessment Act* (CEAA) came into effect in 1995 as a tool for federal decision makers to assess the environmental effects of projects being conducted or funded federally, or which fall under federal regulatory approval (CEAA 2001). Under section 11(1) of the CEAA, a federal environmental assessment is to be conducted as early as is practical in the planning stages of the project. Part II of the CEAA summarizes what projects require a federal cumulative effects assessment. Some of the projects which may be applicable in northeast BC include prospecting for mines or minerals, inter-provincial pipelines or powerlines, and physical activities related to the approval of an oil and gas development plan (CEAA 2001).

A cumulative effects assessment may also be required for projects that may affect navigable watercourses (under the *Navigable Waters Protection Act* 1985), and projects that may affect migratory birds (under the *Migratory Birds Convention Act* 1994).

2.3 Land Use Planning

Issues such as cumulative effects, that require coordinated, strategic-level approaches across a vast geographic area, are best addressed through regional or sub-regional planning processes. In BC, Land and Resource Management Plans (LRMP) form an important tool within the broader framework of cumulative effects assessment and management.

The land and resource management planning process is an important component of British Columbia's land use strategy. LRMPs are strategic planning documents that are used to provide broad resource management direction for all Crown land, including provincial forests and aquatic areas, for a period of approximately ten years. Planning strategies and objectives are meant to combine environmental, social, economic, and resource values while embracing the principles of sustainable development and providing a forum for discussing resource management issues. Input from industry, interest groups, the public, and government agency representatives is an important component of the planning process. Within the study area, the Fort St. John, Fort Nelson and Mackenzie

LRMPs (which include the MKMA) are the principal planning documents used to guide strategic land use decisions.

LRMPs provide recommendations for managing Crown land and resources. These recommendations generally address protected areas within the plan area, general management directions for the entire area, and boundaries, objectives, and strategies for Resource Management Zones (RMZs) and Special Management Zones (SMZs). Resource management in any area, outside of protected areas, is defined by the general management direction, plus relevant RMZ, SMZ, or sub-zone level direction. Management direction for protected areas is generally defined through separate, local-level, protected area management plans (see below).

Industrial activity is permitted in all RMZs, except for protected areas, although resource development and access may be limited or restricted in some zones. RMZs are defined based on resource values, existing economic activity, environmentally important areas, and agricultural land reserve boundaries. Each RMZ contains specific resource values, and includes management objectives and strategies which define the type of activities and level of intensity permitted. SMZs are similar to RMZs but are defined planning areas where the conservation of one or more resource values, such as wildlife habitat, recreation, or community watersheds, is to be emphasized in resource management decisions (Government of BC 2002). In addition to determining locations and intensity of land use activities, LRMPs provide strategic direction for mitigating impacts so that responsible resource development can occur within the planning area. Resource developers and users are required to manage their activities using a range of management tools and strategies, and to operate within the constraints of the regulatory framework.

Lower-level planning within a specific RMZ and SMZ may occur at both the local and landscape level. Local level plans may include park management plans, forest development plans, wildlife management plans, or pre-tenure plans. Local level plans must be within specified boundaries, and must be consistent with the strategic objectives of each LRMP. Landscape level plans are defined under a process called Sustainable Resource Management Planning and through the creation of Sustainable Resource Management Plans (SRMP). SRMPs are meant to provide guidance to operational planning for provincial objectives such as maintenance of biodiversity, economic development, and environmental values. Landscape level planning is designed to meet the objectives of the *Forest and Range Practices Act* of the results-based code, and may complement biodiversity conservation measures being delivered through the BC Protected Areas Strategy (PAS) (BC Ministry of Forests 1999).

Also under the results-based code is a government-sponsored program for creating results-based pilot projects that explore more efficient and less costly ways to combine forest management with the protection of social and environmental values (BC Ministry of Forests 2002). A results-based pilot project is underway for the Fort St. John Timber Supply Area (TSA). Under this project, major forest operators in the Fort St. John TSA are using a coordinated planning process which will incorporate landscape level planning into forestry plans, combine individual forest development plans into one consolidated plan, eliminate the need for individual approval of most site level plans, establish a process for ongoing public involvement, and test certification processes as a means of maintaining or improving environmental performance. The core of the pilot project is a new document called the Sustainable Forest Management Plan.

2.4 Muskwa-Kechika Management Area

The Muskwa-Kechika Management Area (MKMA) is a Special Management Zone. The MKMA spans three LRMP plan areas: Fort St. John, Fort Nelson and MacKenzie.

2.4.1 Muskwa-Kechika Advisory Board

The *Muskwa-Kechika Management Area Act* created the MKMA and a Premier-appointed advisory board to advise on natural resource management in the MKMA. The Muskwa-Kechika Advisory Board (MKAB) is comprised of individuals with a broad range of interests, including, but not limited to, First Nations, conservation organizations, business, labour, and local government. The principal role of the MKAB is to ensure that activities within the MKMA are consistent with the objectives of various management plans. Board members also review Trust Fund proposals (see Section 2.4.3).

2.4.2 Local Level Planning in the MKMA

Local level planning is based on local level strategic plans which are consistent with the MKMA and LRMP objectives and are legislated under the *Muskwa-Kechika Management Area Act*. As stated above (Section 2.3), local level planning provides guidelines for recreation, wildlife management, industrial activity, and protected areas. Some of the local level planning activities in the MKMA are described below.

Prior to the creation of the MKMA, the Muskwa-Kechika Access Management Area had been designated under the *Wildlife Act* (BC Reg. 218/94). Local level planning within the access management area restricted public off-road vehicle access to designated roads in order to protect wildlife and habitat. Additional access management provisions in the MKMA have more recently been associated with LRMPs and pre-tenure plans (see below).

The MKMA Recreation Management Plan was completed in 1997. The plan provides an overview of recreation resources in the MKMA, general management direction for recreation access and use, guidelines for commercial recreation, and specific management direction for five defined recreation categories. A Wildlife Management Plan for the MKMA is currently being developed. This plan is meant to ensure that the MKMA's wilderness characteristics, wildlife, and habitat are maintained over time. The plan will provide resource managers, users, tenure-holders, and the general public with guidelines for wildlife management in the MKMA. Another major type of local plan is the park management plan. There are presently 17 protected areas within the MKMA. Each is subject to management direction provided through a park plan or other strategic plan documents. Presently, recreation, wildlife, and other local level strategic plans do not provide specific direction for industrial activities like oil and gas development.

Oil and gas development in the MKMA falls under a separate planning process. According to the *Muskwa-Kechika Management Area Act*, a pre-tenure plan (PTP) is required before oil and gas tenures can be issued in the MKMA (*MKMA Act* 1998). Oil and gas PTPs promote environmentally responsible development of oil and gas resources (within discrete planning areas) by identifying objectives and strategies for development activities that are consistent with the *MKMA Act*. PTPs must be compatible with other existing or evolving local level or strategic plans. Presently, pre-tenure planning is underway for specific sub-areas of the MKMA. Phase 1 of the Besa-Prophet Pre-tenure Plan (BPPTP) has recently been completed (BC MSRM 2002). The BPPTP provides goals for oil and gas activities in portions of two RMZs - the Prophet RMZ and the Besa-Halfway-Chowade RMZ of the Fort Nelson and Fort St. John LRMPs. Another PTP is in place for the Sikanni drainage within the Besa-Halfway-Chowade RMZ. Additional PTPs that are underway in the MKMA include Suphur/8 Mile, Churchill, Muskwa West, and Halfway-Graham (scheduled for completion in March 2003); Upper Gataga, and Upper Akie/McKuster (scheduled for completion in December 2003); and Besa-Prophet Phase II (scheduled for completion in March 2003). The only PTP that is fully completed is the Upper Sikanni Management Plan (BC MSRM 1995), which was completed in 1995, and which preceded the *Muskwa-Kechika Management Act*.

2.4.3 Research and Projects in the MKMA

One of the roles of the MKMA is to support research activities that have direct links to the mandate and objectives of the MKMA, as outlined in the *Muskwa-Kechika Management Area Act*. To fulfill this role, a trust fund was established between the MKAB and the provincial government (BC Ministry of Sustainable Resource Management 2001). The Muskwa-Kechika Trust Fund receives donations from industry, regulators, the provincial government, and non-government organizations. The research projects funded by the Trust must contribute towards wildlife and wilderness resource management objectives, and integrated management of natural resource development. Projects must also contribute towards maintaining the diversity and abundance of wildlife species and the ecosystems on which they depend.

During the 2001-2002 fiscal year, the trust fund received 91 applications, 35 of which were funded. Projects have been separated into five themes: building an information base; planning support; improving management; advancing applied science; and promoting awareness, involvement, and capacity building. In addition to the CEAMF, which was partially funded under the Trust, some of the major projects that received funding include:

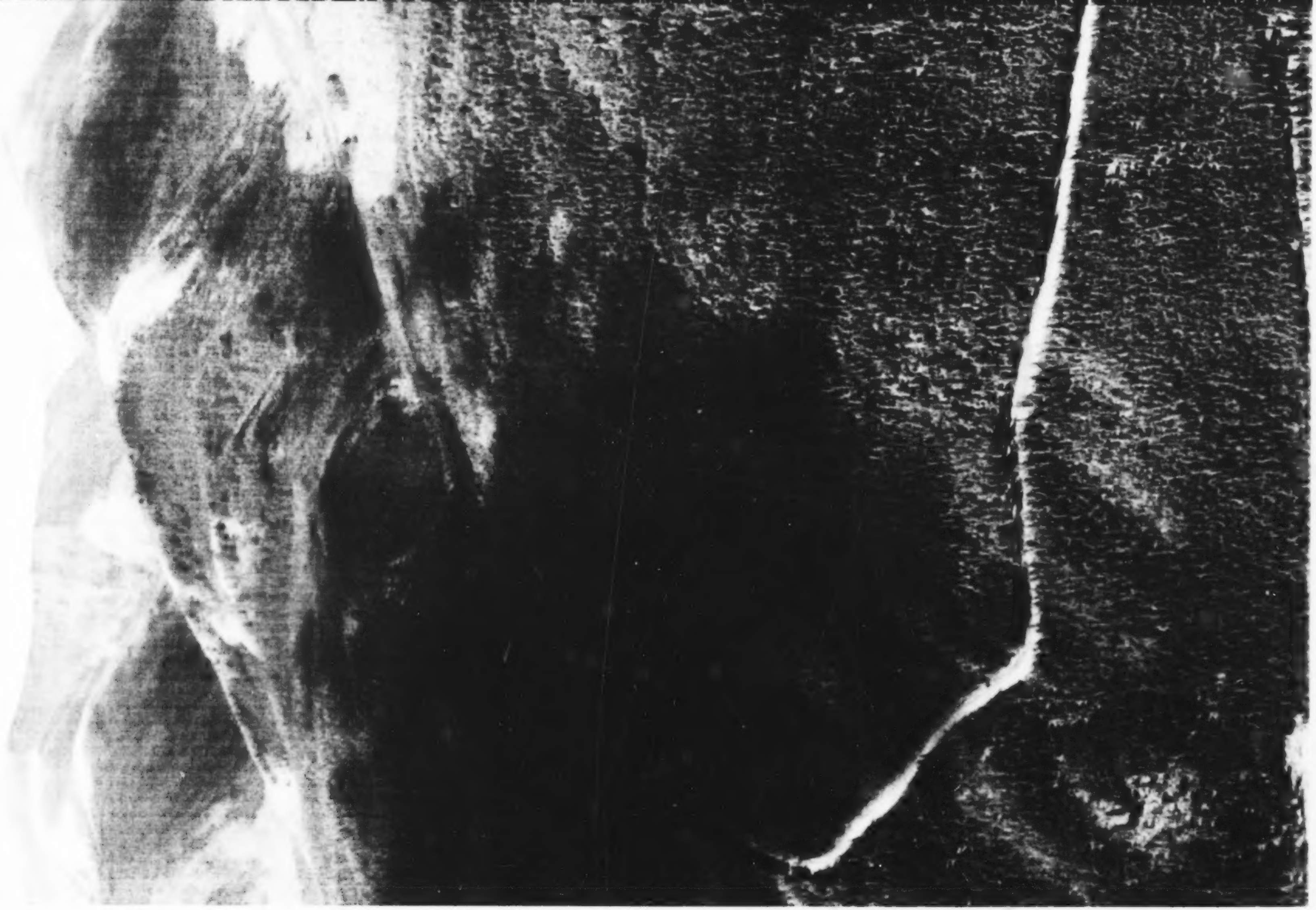
An Ecosystem Approach to Habitat Capability Modelling and Cumulative Effects Management: This project involves developing an information database of the MKMA by defining processes, core areas, typical movements, and specific habitat requirements of ungulates and large carnivores. From a management perspective, the information can be used to identify the best scenarios for accommodating changes associated with increased access (Parker 2002).

MKMA Park Management Planning: Funded projects include continuing public involvement processes for park management planning, conducting inventories and surveys, assembling data, and performing other functions required to support management and planning for protected areas within the MKMA.

Conservation Areas Design (CAD): The CAD will provide a framework for linking landscape level objectives and zoning, including maintaining ecological sustainability with local-level decision-making plans (e.g., pre-tenure plans, park management plans). This may be achieved by developing habitat connectivity models for the Besa-Prophet area that are based upon habitat suitability models developed in other research projects (e.g., Parker 2002).

The role of research in the context of the proposed CEAMF is discussed further in Section 4.4.

CHAPTER 3: REGIONAL ASSESSMENT



3 Regional Assessment

3.1 Overview

3.1.1 Products

The Regional Assessment (RA) provides a broad-scale overview of the state of the environment, and of land and resource uses in the northeast BC study area. The RA summarizes contributors to cumulative effects and those environmental components that are potentially affected. It therefore serves as an information basis for application within the CEAMF (as described full detail in Section 4).

The RA focuses on, and presents a description of land and resource use, and five environmental components: air quality; soils and terrain; aquatic ecosystems; vegetation; and wildlife (Sections 3.2 to 3.7). For each section, information is provided on the following topics to the extent and level of detail that is appropriate and useful:

- baseline setting (i.e., current conditions of environmental features and human use);
- issues of concern (i.e., issues regarding regional matters of concern and potential cumulative effects);
- valued ecosystem components or VECs (i.e., potentially affected environmental components that are of value to people or which have intrinsic value); and
- hot spots (i.e., specific geographic areas of potential concern based on potential conflict between human use and the valued ecosystem component; see Appendix E for a detailed explanation of what the hot spots represent and how they were derived).

The RA also includes 29 maps (listed in Table 3-1), which include baseline and hot spot maps for each discipline. Due to their large size and number, all of these maps are provided together in Appendix H, but are referred to throughout Section 3.

It should be emphasized that the hot spot maps are not limited to disturbances caused by oil and gas activities. As discussed in Appendix E (Hot Spot Map Derivation), many of the hot spot maps relied on a disturbance coverage that was generated for the study area and which overlay 17 themes representing different types of land uses including, by not limited to, oil and gas, forestry, agriculture, mining, urban settlement, recreation, transportation, and access[1]. Many of these activities overlap in the southern part of the study area and have collectively contributed to land clearing and associated habitat loss, and to impacts associated with the proliferation of access (e.g., increased hunting and fishing pressure). These and other impacts are discussed in more detail below, and later in relation to each environmental component.

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[1] Seismic line data was excluded as many of the seismic lines are known to be 25-30+ years old, and therefore, will have revegetated naturally.

3.1.2 Types of Effects

Cumulative effects issues in northeast BC result from various human activities. Effects that are generally cross-disciplinary (i.e., they are not focused on any one environmental component) include the following, based on type of activity:

- **urban and rural settlement**: habitat loss and fragmentation; altered hydrology; air and water pollution;
- **transportation corridors**: habitat fragmentation and barriers to wildlife movement; run-off of oils and chemicals from roads; exotic and invasive species introduction;
- **oil and gas exploration and development**: increased access to remote areas; sensory disturbance of wildlife; habitat loss and fragmentation; impacts from stream crossings;
- **forestry**: vegetation and habitat loss; disruption of natural forest processes such as fire; loss of old growth-dependent species; soil erosion;
- **mining**: acid mine drainage; increased access to remote areas;
- **hydro-electric development**: habitat loss; barriers to wildlife movements; changes to aquatic environments;
- **agriculture and livestock grazing**: habitat loss; run-off of pesticides and herbicides; soil erosion; exotic and invasive species introduction;
- **recreation and tourism**: disturbances to wildlife; vegetation trampling; exotic and invasive species introduction; and
- **fish and wildlife harvest (including hunting, trapping and fishing)**: wildlife mortality; disturbance to wildlife; illegal harvesting.

3.1.3 Mapping

The maps collectively form a database of spatially referenced information. The maps consist of spatial coverages and related attribute tables at a variety of scales that were assembled from files available mainly from the MSRM, MOF, and OGC. The database only includes data that are available for the majority of the study area and that are available free of charge. Full details about the types of data available, sources of data, scale of data, and specific file names are presented in Appendix D[2]. A summary of baseline and hot spot maps is provided in Table 3-1.

In summary, the contents of the database represent an assembly of data including:

- topographic data (at scales of 1:1,000,000; 1:250,000; and 1:20,000) and air photos;
- place names and management boundaries, including protected areas;
- land use and disturbances (human activities and industrial development);
- terrestrial ecosystem mapping, biogeoclimatic data, and watersheds; and
- wildlife habitat and rare and endangered species, fish distribution, soils and terrain.

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[2] All data used for the study (Volumes 1 and 2), including maps, have been provided on CD-Rom.

Table 3-1. List of Baseline and Hot Spot Maps

Figure Title		Fig. #
Component	**Description**[1]	
Land and Resource Use	Generalized Land Use	3-1
	Residential Settlement and Transportation	3-2
	Pipelines and Wellpads	3-3
	Seismic Line Density	3-4
	Protected Areas	3-5
	LRMPs Overlapping Study Area	3-6
	Fort Nelson LRMP	3-7
	Fort St. John LRMP	3-8
	MacKenzie LRMP	3-9
Air Quality	Well Density	3-10
	Hot spots (Sulphur Emissions)	3-11
Soils and Terrain	Soils Classification	3-12
	Soil Hot spots (Acid Sensitivity)	3-13
	Soil Hot spots (Erosion Risk)	3-14
Aquatic Ecosystems	Arctic Grayling and Bull Trout Observations	3-15
	Hot spots (Drainages)	3-16
Vegetation	Biogeoclimatic Zones	3-17
	Sensitive Features	3-18
	Hot spots (Sensitive Features)	3-19
Wildlife	Grizzly Bear Habitat Capability	3-20
	Moose Habitat Capability	3-21
	Marten Habitat Capability	3-22
	Warbler Habitat Capability	3-23
	Caribou Winter Habitat	3-24
	Grizzly Bear Hot spots (Habitat Capability)	3-25
	Moose Hot spots (Habitat Capability)	3-26
	Marten Hot spots (Habitat Capability)	3-27
	Warbler Hot spots (Habitat Capability)	3-28
	Caribou Hot spots (Winter Habitat)	3-29
Disturbance	Disturbance Coverage	E-1

[1] Shaded cells indicate hot spot maps; remaining cells are baseline maps.

In addition to these data types, a number of derivative datasets were developed to generate seamless coverages for a specific theme for the study area, and for data analysis and summary purposes (e.g., the hot spot maps and density maps). These coverages and their attribute tables have been incorporated into the regional database provided. Methodologies for deriving individual hot spot maps are described in Appendix E, while other derivative maps are described in Appendix D in relation to the database.

The database represents the most current digital information base for the study area; however, users of the data should be aware of the following limitations:

- the purpose of the database is to provide a regional overview of both the data available and the environmental characteristics of the study area. If a detailed assessment is being conducted, users should verify that the data is the most current, and determine if more detailed information is available for their specific area of interest; and
- as mentioned above, the data have been provided at a variety of scales. Users should be aware of the consequences of mixing data at different scales, and should select a working scale that is appropriate for the spatial extents of their particular development.

3.2 Land and Resource Use

Section 3.2 describes the types of land uses occurring in northeast BC (Figure 3-1 provides a general overview). All of the activities, with the exception of residential settlements and agriculture, occur to varying degrees in both the Interior Plateau and MKMA sub-regions of the study area. Activities with special significance or management regimes that are specific to the MKMA are described separately.

3.2.1 Setting

3.2.1.1 Residential Settlement

The regional population in northeast BC has been slowly increasing, a trend that is expected to continue. Population growth projections for this region are strongly linked to the intensity of development activity in key resource sectors. Fort Nelson and Fort St. John are the largest urban centres in the study area (Figure 3-2). Outside of these cities, smaller settlements and rural areas are located along major travel corridors. In the Fort Nelson planning area, smaller residential communities are predominately located along the Alaska Highway, including Summit Lake, Toad River, Muncho Lake, Liard River, Coal River, Fireside, Lower Post, and Watson Lake. In the Fort St. John planning area, smaller residential communities include Taylor, Clayhurse, Cecil Lake, Goodlow, Rose Prairie, Montney, Wonowon and Pink Mountain. First Nations communities within the study area include Halfway River, Blueberry and Doig.

3.2.1.2 Transportation

The study area is traversed by a number of transportation corridors (Figure 3-2), which link residential communities, service centers, and industrial areas. The major transportation corridor in the region is Highway 97 (Alaska Highway). In more remote areas of the region, various forms of RoWs (e.g., seismic lines, pipelines, cutlines, well access roads, logging access roads, and transmission lines) provide access and potential access for road and off-road vehicles.

3.2.1.3 Industrial Activities

Oil and gas exploration and forestry are the dominant industrial land uses, regionally; however, some active mineral extraction and exploration also occurs. Other forms of industrial land use include agriculture, hydroelectric, transportation, communication, and utility corridors.

Oil and Gas

The Peace-Liard region is the only part of the province where large commercial quantities of natural gas, and more limited amounts of oil are produced. Approximately 2,600 oil and gas pools have been identified in northeast BC and about 12,000 wells have already been drilled. The development of several large gas fields in the region has resulted in the creation of seismic lines, pipelines and associated facilities, access roads, and well sites (Figures 3-3 and 3-4).

Over 250 oil and gas companies operate in northeast BC and the industry is one of the region's largest employers. The level of development activity associated with this industry is projected to increase. It is estimated that at the 1994 rate of production, more than 50 years of proven plus potential natural gas reserves remain in northeast BC, exclusive of any impacts resulting from the creation of new protected areas or the implementation of forest practices code requirements (ARA et al. 1996). Provincially, the sales value of oil and gas production was estimated at $5.6 billion in 2001 and recent statistics indicate oil & gas crown revenue will exceed forestry crown revenue as the largest source of revenue from British Columbia's natural resource sector.

The study area also includes reserves of coal bed methane. Although production has yet to be initiated in British Columbia, the Ministry of Energy and Mines is in the process of implementing a strategy to establish coal bed methane as a clean, environmentally safe energy source that can be developed to service local, domestic and export markets.

In May 1998, the provincial government introduced the Oil and Gas Initiative (OGI) to encourage British Columbia's oil and gas sector to expand and make it easier for oil and gas firms to do business in British Columbia (BC Ministry of Energy and Mines 2003). The Oil and Gas Initiative will provide regulatory efficiencies, tax efficiencies, and investments in infrastructure. The government aims with the support of the Oil and Gas Initiative to double oil and gas production in the province.

Forestry

Active timber harvesting and processing presently occurs in various locations throughout the study area. Spruce, pine, aspen, and cottonwood are the principle merchantable species. The study area encompasses all of the Fort Nelson and Fort St. John Timber Supply Areas (TSA) and parts of the Mackenzie and Cassiar TSAs. It is expected that forest harvesting will be sustained or enhanced to provide new opportunities in the region. LRMP objectives regarding forestry are to minimize timber losses, manage forests at the landscape unit level, and increase the area and productivity of the forest land base.

Mining

The potential for long-term extraction of coal from the Peace River coal field is moderate to high in some places, although there are only a few places in the Dawson Creek area where there is active coal mining. There are no major operating coal mines in either the Fort St. John or Fort Nelson areas. There are potential metallic mineral reserves in the western mountains, and coal and industrial minerals in the foothills. Additionally, there are areas (usually near industrial or residential areas) of active aggregate mining (sand and gravel) for road construction, industrial developments, and building structures.

Agriculture

Agricultural has a long history in the North Peace and Fort St. John areas. The Peace River region accounts for over one third of the province's Agricultural Land Reserve (ALR). The industry has been, and continues to be, dominated by the production of grain and oilseed crops. Additionally, the Peace River area is one of North America's highest capability areas for cow/calf production. The ranching sector has grown considerably over the past few years, and there has been recent growth in beef and forage crop production, and expansion of grazing and agricultural leases on Crown land. Slow, steady growth is expected, along with expansion into more specialized activities.

Hydroelectric Projects, Communications, and Utilities

Several large and small hydroelectric projects occur within the region. Larger projects include the Gordon M. Shrum Generating Station at the W.A.C. Bennett Dam at the head of the Peace River Canyon, and the Peace Canyon Dam and Powerhouse located near the town of Hudson Hope. No potential micro hydro sites have been identified in the region. Although demand for electricity in BC is increasing, it is unlikely that the potential Liard River resource will be developed in the foreseeable future. There are also numerous communication, transportation, and utility corridors throughout the region, and additional structures of this nature will likely be required.

3.2.1.4 Non-industrial Activities

Outside of residential areas and transportation corridors, the principle land uses for non-industrial purposes within the study area include public access, recreation, tourism, and First Nations traditional uses. Public access occurs along all accessible RoWs. Public use is permitted on most industry roads on Crown land. Off-road use by ATVs or snowmobiles also occurs on seismic lines, pipelines, and inactive roads, and is prevalent year-round, but particularly during the hunting season. De-activation of roads and roll-back of access corridors following industrial use has become the norm; however, ATVs and snowmobiles can still access such corridors long after they have been de-activated. There are no data to quantify levels or frequency of pubic use of RoWs. Under the Access Management Area Regulations of the *Wildlife Act*, ATV use (excluding snowmobile use) is restricted in officially-designated Access Management Areas. The MKMA is a designated Access Management Area as are smaller areas within Northeast BC, including the Mount Klingzut closure area just outside the MKMA's eastern border.

Outdoor recreation and tourism account for a small but growing portion of the regional economy. Northeast BC has always had a high international profile for backcountry hunting and fishing opportunities. Guided hunting and fishing trips account for most of the region's tourism revenue, but other backcountry pursuits such as wildlife viewing, photography, and adventure tourism are gaining in popularity due to the natural beauty of the region, and to its abundance and diversity of wildlife. All flowing waters and most lakes in the region are open year-round for sport fishing within provincial seasons and regulations. Most lakes and waterways are accessible by road, and many offer world-class fishing experiences for species such as lake char, northern pike, walleye, arctic grayling, bull trout, rainbow trout, and mountain whitefish.

Non-consumptive recreational pursuits are less common than hunting and sport fishing, but they do occur at a number of designated and informal recreation sites throughout the region. Most activities are highly dependent on the region's wilderness recreation values such as its scenic quality, and its diversity and abundance of fish and wildlife. Popular recreation activities in the region include hunting, hiking, camping, scenic and wildlife viewing, cave exploring, kayaking, canoeing, fishing, jet-boating, mountain-biking, cross-country skiing, snowmobiling, and use of all-terrain vehicles (ATVs). All-season highways, logging roads, and seismic lines comprise the principal access corridors for recreational users. Recreational activities occur by regional residents and tourists. Non-resident recreational activities occur primarily as part of commercially-guided excursions.

The demand for wilderness tourism is expected to increase with the anticipated growth of commercial recreation opportunities (Dawson Creek LRMP 1999). Additionally, highway and community tourism has been increasing. The Northern Rocky Mountain and Alaska Highway Tourism Association has attempted, in recent years, to encourage tourists to travel off the Alaska Highway into wilderness areas of the northeast. By working with guide outfitters, the Tourism Association is hoping to increase the profile of wilderness eco-adventure tourism in the northeast, as a whole, and in the MKMA protected areas, in particular. The maintenance of pristine or natural settings and the availability of a variety of outdoor recreation opportunities are critical to sustaining the viability of the wilderness recreation and tourism sectors.

First Nations traditional activities on the land include consumptive uses such as hunting, trapping, fishing, and berry-picking; non-consumptive uses focus on spiritual and ceremonial practices.

Hunting and Trapping

Hunting is the most common non-commercial resource use. Quality hunting and guide outfitting experiences exist in the study area due to the diversity of landscapes and wildlife. Hunting occurs year-round by local First Nations communities, and by other local residents and guide outfitters during hunting seasons. Guide outfitting is an important revenue-generating business which serves a varied clientele from provincial, national, and international locations. Private hunting occurs in season on Crown land throughout the study area. The most commonly hunted species are moose and elk. Other animals hunted less frequently include caribou, deer (white-tailed and mule), black bears, grizzly bears, sheep, goats, and wolves. Groundbirds (e.g., grouse) and waterbirds are also hunted. Existing access roads are used extensively by hunters as the jumping-off point for single and multi-day trips. Many areas are accessible by standard trucks and vehicles. Hunters mainly use ATVs and snowmobiles for off-highway use.

Trapping is socially and economically important to both local and regional economies. Trapping occurs throughout the study area, and is an important traditional use, although it is diminishing in commercial importance. The diverse landscapes and habitats of the region are home to a variety of commercially harvested furbearers including marten, fisher, lynx, coyote, wolf, fox, beaver, and squirrel. The most commonly harvested of these are marten, beaver, and squirrel. The trapping sector, however, is experiencing an economic decline due to a deteriorating fur market.

3.2.1.5 Protected Areas

Provincial parks and protected areas (referred to collectively, as protected areas for simplicity) comprise about 9% of the study area (Figure 3-5). These protected areas are legally defined areas that have been set aside to protect representative ecosystems or special biophysical or cultural heritage features, and/or to provide recreation opportunities (where appropriate) related to the area's natural and cultural setting. In general, resource extractive activities are prohibited within protected areas in northeast BC, with the exception of First Nations traditional activities, grazing, and guide outfitting. Directional drilling for oil and gas is permitted beneath some protected areas.

The largest protected areas are found within the MKMA, namely the Northern Rocky Mountains, Kwadacha Wilderness, Muncho Lake, Graham-Laurier, Denetiah, Redfern-Keily and Liard River Protected Areas. Outside the MKMA, Klua Lakes, Maxhamish Lake, and Thinatea are the largest protected areas. Several of the MKMA protected areas are considered to have the best representation of significant landform features in the province. These include the Grand Canyon of the Liard, the hoodoos along Wokkpash Creek, and the rugged alpine features of the Denetiah, Northern Rocky Mountains, and Redfern-Keily Protected Areas (BC Parks 1999).

There are several ecological reserves (ER) within the study area, including Smith River ER just south of the 60th parallel; Portage Brule Rapids ER just outside the MKMA northern border near Highway 97; Grayling River Hot Springs ER north of the Liard River; Fort Nelson River ER just north of Fort Nelson; Kotcho Lake Islands ER northeast of Fort Nelson; Parker Lake ER just west of Fort Nelson; Cecil Lake ER northeast of Fort St. John; Clayhurst ER near the BC-Alberta Border in the southern part of the region; and Sikanni Chief River ER within the MKMA. Other than scientific research and some types of low-impact recreation (in select ERs only), human use and resource development activities are excluded from ecological reserves.

3.2.1.6 Muskwa-Kechika Management Area

The MKMA has been identified as having significant resource and wilderness values. Approximately 25% of the Management Area consists of parks and protected areas; 75% is comprised of Special Management Zones (SMZs). Recreation and tourism are permitted throughout the area, while economic and industrial development such as mining, oil and gas, and logging are permitted only within the SMZs and Special Wildland Zones (where all activities other than logging are permitted). Access routes to the MKMA include roads (to some protected areas) and seismic lines, and access is achieved either on foot, horseback, or skis, or by aircraft, snowmobile or dogsled. As previously noted, ATV access other than by snowmobile is restricted within the MKMA under the Access Management Area Regulations.

Although there are few producing or proven oil or gas reserves within the MKMA (the only known past production area was just inside the MKMA within the Sikanni drainage), exploration drilling has been done in the area. There are also reserves immediately adjacent to the MKMA. The Ministry of Energy and Mines has estimated that the MKMA contains 8 trillion cubic feet of gas, with the highest concentration located in the eastern portion of the Management Area. Since about 1993, oil and gas tenure applications for the MKMA have been deferred pending pre-tenure planning. In 2002, the first pre-tenure plan for oil and gas was completed for the Besa-Prophet area of the MKMA.

Three mineral formations overlay the MKMA: the Gataga Kechika lead and zinc belt; the Eastern Foothills lead and zinc belt; and the Churchill copper belt (ARA et al. 1996); however, little mineral exploration activity has occurred even though the Ministry of Energy and Mines states that significant potential for mineral resource development exists. Some mining occurred previously in the MKMA as part of the Churchill Copper Project, which has since been closed. The remoteness of the area has been the main factor that has limited exploration and production activities.

Opportunities for wilderness tourism and background recreation in the MKMA are considered to be significant. The main features and attractions in the area are closely linked to hunting and fishing, but increasingly, emphasis is being placed on visual quality and adventure tourism (BC Parks 1999). There are an estimated 17 to 20 guide outfitting territories in the MKMA. Backcountry recreation activities include hiking, fishing, horseback riding, wildlife viewing, nature appreciation, river boating, and snowmobiling.

With regards to forestry, there has been limited interest in the area's forest resources due primarily to difficult access and low volumes combine to limit interest. Trapping is another land use activity that occurs in the MKMA. There are approximately 35 traplines, many of which are owned and operated by First Nations (ARA et al. 1996).

3.2.1.7 Land Use Plans

Three LRMPs (Figure 3-6) cover the study area: Fort Nelson (Figure 3-7), Fort St. John (Figure 3-8), and Mackenzie (Figure 3-9). These LRMPs provide general and specific management directives to guide all uses on Crown land in the region.

3.2.2 Issues

As described above, the primary land uses in northeast BC include energy and mineral exploration and development, aggregate extraction, timber harvesting, hunting and outfitting, trapping, agriculture, residential occupancy, and summer and winter recreational activities. In general, the only facilities to be found in the MKMA are guide outfitting and fishing camps, trapper cabins, and trails. Use is primarily by guided hunting and fishing trips, but private recreational users are prominent in more accessible places. Each of these activities, individually or in combination, can result in specific and cumulative impacts to the biophysical environment or to socio-cultural values. The discussion below focuses on the issues resulting from oil and gas activities in relation to their effects on other land uses in the region. Issues are summarized below for the Interior Plateau (i.e., the lands generally outside and east of the MKMA) and MKMA sub-regions.

3.2.2.1 Interior Plateau

Access Management

Considerable access to the Interior Plateau exists, mainly in the form of seismic lines, which are used by off-road vehicles. Some graded roads and utility corridors (i.e., pipelines, transmission lines) provide further access. Increased access into previously inaccessible or difficult to reach hinterland areas is one of the major issues of concern in the region, and has been raised by government agents and stakeholders. More access increases the opportunity for recreationists and commercial resource users to hunt, fish, trap, and travel throughout a larger area. Although corridors provide a source of forage for wildlife and domestic stock, and a means for recreation and motorized access, they can fragment habitats. It is generally recognized that resource roads have increased public access to this area, and that the restrictions will be required in important wildlife areas.

LRMPs provide some direction for access management, and in recent years there has been more co-operation between resource management agencies and industry in planning, developing, and in some cases, rehabilitating access corridors. While the LRMPs provide opportunities to create communication, transportation, and utility corridors outside of protected areas to support resource development in the region, an objective of the plans is to ensure that future development utilizes existing corridors and sites, wherever possible. Additionally, the development, maintenance and/or upgrade of utility corridors must be done with sensitivity to high capability wildlife habitat, recreational values, and visual quality objectives. Unused corridors are to be rehabilitated where feasible.

Impacts to Forest Operations

Oil and gas activities may result in impacts to forest operations, thus leading to conflicts between these two major resource use sectors. Development of oil and gas-related facilities, including RoWs in areas with harvestable timber, may result in a temporary or permanent loss of forest production through reduction in the harvestable land base. Additionally, a major concern of timber operators is the continued and safe access to their sites, which may sometimes be impeded in active oil and gas operating areas.

Impacts to Trappers

Decreased opportunity and success for trapping are the most significant issues for the trapping sector. The specific concern for trapping is that construction of oil and gas-related facilities and infrastructure can have a negative effect on furbearer habitat that, in turn, would lead to a decrease in populations, and thus, lower trapping success in the area. Another important concern is the need to manage motorized access to previously inaccessible areas that may be used by trappers. Disruption or destruction of traplines and trapper cabins are also issues of concern for trappers. Cumulative impacts may result from the incremental introduction of industrial facilities into hinterland areas, which typically occurs after access is opened up by one developer. Access control and co-ordinated access management among industrial users is an issue for trappers.

As stated in the LRMPs for the Interior Plateau, a major concern for many trappers is the need for adequate notification of impending land and resource developments that could detrimentally affect their interests. In an attempt to provide appropriate notification, the provincial Ministries of Water, Land and Air Protection; Forests; and Energy and Mines (Energy and Minerals Division), in conjunction with the BC Trappers Association, have implemented a program to ensure that trappers are adequately notified of impending developments, provided that the trapper has authorized the release of personal information.

Impacts to Sport Fishers, Hunters, and Guide Outfitters

Decreased opportunity and success for hunting and fishing are the most significant issues for the hunting and fishing sectors. A concern is that construction and operation of industrial facilities will have a negative effect on habitat, which in turn, would lead to a decrease in populations, and thus, lower success of hunting and sport fishing in the area. Another concern is that public access will be impeded due to the active use of RoWs for industrial activities, particularly after ground freeze-up (i.e., late fall and winter), which is the prime period for industrial construction in the northeast. Private hunters and fishers generally view increased access via new or improved industrial RoWs favourably; however, guide outfitters, in general, are concerned that increased access to wilderness areas will lead to losses and damages at outfitter camps; increased traffic that disturbs game species and changes their movement patterns; increased competition for wildlife; the need to alter scheduled outfitting trips or move camps to avoid construction periods or locations; and, importantly, the diminishment of the wilderness experience they are selling to their clients.

Impacts to Non-industrial Uses

Effects of oil and gas activities on non-industrial users (namely First Nations and other public users of the land), include loss or degradation of traditional hunting, trapping, fishing, and gathering areas; degradation or intrusion into culturally or spiritually important areas; sensory disturbances to recreational users due to noise or dust caused by construction; impediments to access to certain areas during active construction periods; and degradation of the visual quality of the region. Additionally, unmanaged access may have negative effects on users who are looking for a wilderness experience (e.g., those taking horse packing trips).

3.2.2.2 Muskwa-Kechika Management Area

The above issues apply, to lesser or greater degrees, in the MKMA. Issues relating to competing uses by industrial sectors occur in some areas, but typically, the limited use of the area for forestry, and the presence of access management protocols help minimize these issues. Access is one of the greatest threats to wildlife and wilderness, and is a major issue for users of the wilderness features in the MKMA. Note that the MKMA Act requires land managers to manage the MKMA for a lesser level of impact than may occur in other areas.

3.2.3 Hot Spots

Areas that are intensely developed are more likely to result in conflicts and other types of cumulative effects among land users. While areas of greater potential conflict among users may be considered as a type of hot spot, a hot spot map was not developed for land and resource use components.

The types and intensity of land use activities across a region or sub-region are generally defined through planning processes, such as LRMPs, which are intended to provide strategic level management direction, thus balancing lower and higher intensity use areas across vast land bases. Because LRMPs have defined, through multi-stakeholder processes, areas where oil and gas activities can occur in relation to other types of land use, it is inappropriate to define such areas a hot spots for cumulative effects for land use.

For similar reasons, and due to sensitivity of information, hot spot maps were not developed for First Nations traditional uses; however, those who wish to map areas of concern for their own purposes could use methods similar to those for identifying regional hot spots which would include selecting spatially-explicit areas of traditional use and interest (e.g., hunting/fishing camps, historical hunting grounds, spiritual sites), a process that would include indigenous knowledge.

3.3 Air Quality

Air quality is, by definition, a cumulative effects issue, as each new development will incrementally add to the overall air pollutant levels of a region. Air quality is affected not only by local pollution sources, but also by long-range transport of pollutants from distant sources. Potential sources of both air and noise emissions from oil and gas activities include:

- vehicles and equipment used for seismic exploration equipment;
- well test flaring for exploration drilling;
- production and processing facilities; and
- transmission pipelines, including compressor stations.

The Fort St John/Taylor region has heavy industry present in its airshed (e.g., pulp mills, sawmills, and other wood products plants) in addition to oil and gas activities. Because of the cumulative effects of these activities and the desire to mitigate potential detrimental increases in air pollution, the region has initiated the development of an air quality management plan.

Oil and gas well densities in several regions of the Interior Plateau are quite high, particularly around Fort St. John and around the Kwokullie Lake on the Eisho Plateau (Figure 3-10). The southern region of the Interior Plateau also has the highest human population density in the study area. Because of the high density of oil and gas development and the relatively high human population density, cumulative effects of air emissions are potentially of concern and need to be addressed for proposed new facilities in these areas. Factors other than well density, which influence the potential for cumulative effects include sulphur content and expected well throughput. Sulphur content is known and reported to the OGC, and is, therefore, available for use in assessing potential impacts.

Sulphur dioxide (SO_2) is considered to be the key air pollutant associated with oil and gas activities, and so, can be used as the indicator pollutant to assess the potential cumulative air quality impact of proposed developments. The acceptability of the resulting ambient SO_2 concentrations can be judged by comparing the expected maximum SO_2

concentrations to ambient air quality criteria. These criteria can be either regulatory or receptor based.

Previous modelling of well test flaring with H_2S concentration in the 30% range in the Interior Plateau region has shown concentration values of 900 $\mu g/m^3$ SO_2 to distances of 10 to 20 km. Although maximum H_2S concentrations tend to be lower in this region (in the range of 4–6%, with a significant portion of the natural gas being 'sweet,' or low in sulphur content), these findings indicate that areas with several air emission sources can experience cumulative effects on air pollutant concentrations.

Little to no oil and gas development has occurred in the MKMA to date. The area is also very sparsely populated, with few communities. Air quality associated with industrial activities, therefore, is not yet of concern.

Areas of continuous sulphur emissions activity, based on sulphur emission density (i.e., volume emission/land area), are indicated as potential hot spots in Figure 3-11. As would be expected, clusters of high densities are correlated with certain areas of oil and gas activity in the Interior Plateau, particularly in the southern portion of the region. The most intense 'hot spots' on the SO_2 emission intensity map do not necessarily imply that BC Ambient Air Quality Objectives are exceeded. Rather, the hot spots indicate areas where objectives may potentially be exceeded. Regarding the MKMA, if monitoring (or multiple-source dispersion modelling) of some of the areas that appear on the emission intensity map as the most intense shows non-compliance with BC Ambient Air Quality Objectives, then similar areas in the MKMA would also be expected to do so. Conversely, if non-compliance is uncommon in the most intense areas at present, then similar areas in the MKMA would also be expected to be compliant. The topography in the MKMA, however, might be expected to be more conducive to potential exceedances than the flatter terrain in the eastern part of the study area, for example, as occurs in the foothills development regions in Alberta.

3.4 Soils and Terrain

3.4.1 Setting and Issues

Continued development in the Interior Plateau and MKMA poses several challenges to quantifying cumulative effects from a soils and terrain perspective (see Figure 3-12 for soils classification). Main impacts of concern, discussed below, are soil acidification, changes to overall soil quality/capability, and long-term effects on sensitive permafrost areas.

3.4.1.1 Soil Acidification

Soil acidification impacts are typically measured in relation to the Potential Acid Input (PAI) from industrial or other sources. While a large impact from PAI is not expected in either the MKMA or the Interior Plateau, confidence in predicting the impact of acid deposition is low due to the lack of research and the lack of regional objectives for acceptable PAI levels.

Interior Plateau

Luvisolic and Cryosolic soils are dominant in the Interior Plateau, and are considered to have low sensitivity to PAI. Minor areas of Dystric Brunisols have been identified, including areas east of Highway 97 from Pink Mountain north to Trutch, and along the Fort Nelson River valley. Areas of sandy Luvisols may also occur throughout the Interior Plateau, but this needs to be verified through improved baseline information gathering. With the concentration of oil and gas development occurring in the Interior Plateau, acid deposition monitoring remains important, but impacts are expected to be low given the buffering capacities of the soils.

Muskwa-Kechika Management Area

Acidification effects on regional soils are assessed based on the extent of sensitive soils, and the degree of impact that PAI have on these soils. Based on available soils information, there is a limited area of highly sensitive soils in the MKMA. The primary concentrations are at higher elevations in the Rocky Mountain Foothills, and in proximity to many rivers and streams in the area surrounding the Cassiar Mountains, including the Kechika River and its tributaries. These areas have sandy soils with acidic conditions and low Cation Exchange Capacities (CEC). Sensitivity ratings are based on an assessment of the pH decrease that the addition of acidifying inputs is likely to have on the buffering capacity of a soil. Specifically, areas with Dystric and Sombric Brunisolic soils are considered to be highly sensitive to acid inputs. Moderately sensitive soils include Eutric and Melanic Brunisols; however, it is also possible that areas with sandy Luvisolic soils would be considered sensitive. Baseline mapping information will need to be improved in order to make such an assessment.

3.4.1.2 Soil Quality/Capability

Interior Plateau

The Interior Plateau shares many of the same concerns with the MKMA, with the exception of two factors. Relatively level topography and lower elevation eases concerns about erosion on steep and/or unstable slopes, but raises issues of its own. Agricultural activity in the Fort St. John area is particularly sensitive to improper soil management practices and maintenance of soil quality/capability; moreover, given the minor extent of suitable agricultural land, any area that is taken out of production will have a greater relative effect than the same disturbance in a forested area.

Muskwa-Kechika Management Area

Effects on soil quality/capability are more readily quantifiable. As with acidification, the cumulative effects of loss of soil quality/capability are assessed by the extent and degree of impact. Particular attention should be given to highly productive soils (high capability), riparian soils, and to soils that present reclamation challenges (e.g., soils that are highly erodible, or on steep or unstable slopes).

Loss of soil productivity is a concern for a variety of land uses, including agriculture, forestry, First Nations traditional use, conservation, and hunting.

3.4.1.3 Permafrost Areas

Interior Plateau

Concerns about disturbances in permafrost areas have recently been identified. Much of the Interior Plateau area has permanently frozen, primarily Organic Cryosolic soils. In fact, most of the land east of the Fort Nelson River is permafrost. Vegetation displaced by disturbance takes significantly longer to re-establish during the short growing season here. Additionally, deleterious effects are being noted along pipeline RoWs. The heat generated by pipelines during operation thaws the area immediately surrounding the pipe. When combined with removal of tree cover this contributes to pronounced subsidence across the entire RoW over the years to come; however, even without pipeline impacts, tree removal and activity along cutlines increase the risk of subsidence. This situation introduces significant concerns, including the following:

- ponded water in the subsided trench alters natural drainage patterns, and may be an obstacle for wildlife crossing;
- in mineral Cryosolic soils, subsidence contributes to erosion by the alteration of natural drainage. As water runs down the newly created trench, mineral material is carried with it. Since it will be carried until reaching a low area, commonly a crossing drainage channel, sedimentation of waterways is likely;
- in either case, the depth of cover material over the pipeline is reduced, creating safety and contamination concerns surrounding pipeline integrity; and
- ATV traffic has a high impact on vegetative cover in permafrost areas.

Muskwa-Kechika Management Area

Only one small area of Cryosolic soils has been identified in the MKMA, northwest of Trutch, on the north side of the Prophet River.

3.4.2 Hot Spots

3.4.2.1 Acid Sensitivity

Risk ratings for sensitivity to PAI have been assigned based on the ability of the regional soils to buffer the impacts of soil acidification (Figure 3-13). Only a few relatively small and isolated areas occur as soil acid sensitivity hot spots.

High risk soils have low buffering capacities due to low pH levels, low CECs, and relatively low calcium reserves. They are primarily derived from coarse textured fluvial or glaciofluvial parent materials, and are classified as Dystric or Sombric Brunisols. Eutric and Melanic Brunisols are considered to be moderately sensitive to PAI, and are also developed on glaciofluvial material. The majority of soils in the region have low sensitivity; these soils fall into two categories. Upland mineral soils are mostly Luvisolic, with higher pH, an increased cation exchange capacity, and higher calcium reserves. Organic soils and Gleysolic mineral soils are also rated as low risk due to a number of factors.

These soils are influenced by seepage and/or shallow water tables. The influence of water moving through these coils complicates the interpretation, in that it is considered to provide a buffering effect, even though absolute levels of calcium are often similar to those found in moderately sensitive soils. While bogs and nutrient-poor fens would be rated as moderately sensitive, these wetland classifications will need to be established on a project-specific basis, as they cannot be identified solely through soil classification (i.e., Mesisol).

3.4.2.2 Erosion Risk

Erosion risk categories have been established using different criteria for agricultural and forestry land (Figure 3-14). Erosion risk is minimal for all but numerous small and isolated areas.

With no litter layer and an absence of well-established vegetation rooting, agricultural soils are at greater risk of significant erosion on gentler slopes than are forest soils. For agricultural areas, high risk areas are those with slopes greater than 10% (5°), moderate risk slopes are between 6 and 9% (>3-5°), and low risk areas have slopes of less than 6% (0-3°). In forested areas, however, high risk slopes are those greater than 45% (>24°), moderate risk slopes are 30-45% (16.5-24°), and any areas with slopes less than 30% (<16.5°) are considered to be low risk. Erosion control measures are essential for any moderate or high risk areas. Loss of topsoil degrades soil quality, can compromise slope stability, and often leads to sedimentation within the affected watershed.

3.5 Aquatic Ecosystems

3.5.1 Setting

3.5.1.1 Physical Environment

Geomorphological and biogeochemical characteristics largely determine structure and function of aquatic communities in the study area. The area designated as the Interior Plateau for this project roughly corresponds to the Alberta Plateau and Liard Plateau physiographic regions (Holland 1976). The northern portion is part of the Taiga Plains Aquatic Ecoprovince (Perrin and Blyth 1998), the oldest landmass in British Columbia. This area is a remnant of a large inland sea that was situated at an elevation of approximately 450 m above present mean sea level. The bedrock of this area is shale, which is largely unmodified since last glaciation. That parent material weathers rapidly, producing naturally turbid surface waters and deep river channels that cut into the plains.

The geologic history of this area has produced an undulating topography that is dominated by extensive wetlands, poorly drained soils, and slow, meandering rivers. There are no large lakes in the Interior Plateau, but small lakes are abundant. The wetlands include black spruce bogs that are characterized by acidic conditions, slow decomposition of organic matter, expanses of peat, and tea-stained colour of water due to leaching of tannins and lignin's from surrounding organic matter. Streams typically originate on the organic peat lands, and are characterized by meandering large-channel morphology and average gradients less than 0.5%. Typical streambed material is composed of organic fines. Sand, gravel, and cobble substrates are typically absent.

The southern portion of the Interior Plateau area rises to elevations of 1500 m on the Halfway Plateau Terrestrial Ecosection, and declines to the lowlands of the Peace River watershed. Soft shale is the typical bedrock, and weathering produces deeply-incised river channels and naturally turbid mid-order rivers and streams. Suspended sediment levels in headwater streams are relatively low. Soils are poorly drained, resulting in large expanses of bog and wetland. There is an absence of large lakes. Colour associated with leachates from bogs is moderate (e.g., 30 TCU) in high-order reaches of the lower Beatton River, but at higher elevations, less staining of water occurs.

Drainages in the western MKMA portion of the study area are mountainous, resulting in abundant, high-gradient, headwater streams, and small lakes that originate in the alpine and flow into large river basins including the Kechika, Liard, Muskwa, Prophet, Sikanni and Halfway Rivers. Erodability is low to moderate at high elevations, producing relatively clear streams with abundant riffle and pool sequences. At lower elevations, turbidity increases as the larger streams join to form large rivers. Wetlands are not extensive in these western portions of the study area, although they are locally present near slow-flowing streams that characterize valley bottoms formed by past glaciation. Trees are often absent at lowest elevations in these valleys due to cold air drainage.

Phosphorus concentration in surface waters, particularly in spring, is a key indicator of potential biological production in aquatic systems. In a review of very limited chemical data from the Taiga Plains and Peace Plains Aquatic Ecoprovinces (Interior Plateau in this study), Perrin and Blyth (1998) found most total phosphorus (TP) concentrations were high compared to many other aquatic ecoprovinces of British Columbia. While the available data reviewed by Perrin and Blyth (1998) was sparse and cannot be considered representative of the complete Interior Plateau study area, reported phosphorus concentrations of 30 µg/L to 240 µg/L does indicate a potential for highly productive lakes and streams, particularly in the Peace River Valley. These data are supported by the presence of high concentrations of total dissolved solids (100–400 mg/L), also indicating potential for high biological production. In high order river reaches, the pH is moderately alkaline (7.7 to 8.3) due to alkaline carbonate leachates derived from shale parent materials, thus indicating high acid neutralizing capacity. Although data are lacking for most bog areas, localized acidity associated with acid bog conditions is expected.

In the MKMA, only incidental chemical data were found in the databases received by Perrin and Blyth (1998). The data indicated that high TDS concentrations (up to 300 mg/L) occur mainly in the Muskwa Ranges and Liard Plateau where there has been a long history of fire. In other areas of the MKMA, TDS concentrations are extremely variable, with relatively high concentrations found in the east, and lower concentrations found at higher elevations in the west. These observations may indicate that nutrient deficiency increases with rising elevation to the west, and lower nutrient deficiency is associated with lower elevations to the east. When coupled with spatial distribution of turbidity associated with erosion, areas of high-elevation, clear, nutrient-deficient headwaters are found to the west grading to more nutrient-rich, higher order, turbid, low-elevation rivers to the east.

3.5.1.2 Fisheries Resources

Approximately 40 fish species occur within the study area. The majority of these have "downstream" or "intermediate" distributions within the drainage systems they inhabit, and are typically found in the lower and middle reaches of mainstem rivers and larger tributary streams and lakes. Many of these species, including white sucker *(Catostomus commersoni)*, lake chub (*Couesius plumbeus*), finescale dace (*Phoxinus neogaeus*), and brook stickleback *(Culaea inconstans)* have broad tolerances, and are able to complete their life cycles in habitats of relatively low sensitivity. Two notable exceptions to this general distribution pattern are bull trout (*Salvelinus confluentus*) and Arctic grayling (*Thymallus arcticus*). These species occur in both migratory and stream resident forms, and occupy a variety of habitats based on season and life phase, including habitats of high sensitivity to human disturbance.

Several fish species that are of special concern provincially occur within the study area (British Columbia Conservation Data Centre 2002). In the Fort St. John Forest District, goldeye (*Hiodon alosoides*) and bull trout are blue-listed (vulnerable), and the spottail shiner (*Notropis hudsonius*) is red-listed (threatened). In the Fort Nelson Forest District, goldeye, bull trout, Dolly Varden (*Salvelinus malma*), and inconnu (*Stenodus leucichthys*) are blue-listed, and cisco (*Coregonis artedi*). Arctic cisco (*Coregonis autumnalis*), emerald shiner *(Notropis atherinoides)*, spottail shiner, and ninespine stickleback (*Pungitius pungitius*) are red-listed. In the Mackenzie Forest District, bull trout and Dolly Varden are blue-listed, and the Williston Watershed population of Arctic grayling is red-listed. In addition, Haas (1998) compiled a list of indigenous fish species or individual populations that did not hold any provincial conservation status, but were possible candidates for "regional and/or future conservation consideration". Arctic lamprey (*Lamptera japonica*), chum salmon, pygmy whitefish (*Prosopium coulteri*), round whitefish (*Prosopium cylindraceum*), northern pike (*Esox lucius*), trout-perch (*Percopsis omiscomaycus*), the Liard Hotsprings population of lake chub, flathead chub (*Platygobio gracilis*), walleye (*Stizostedion vitreum*), and brook stickleback were among the species identified for the Peace and Liard drainages. While pearl dace (*Margariscus margarita*) and spoonhead sculpin (*Cottus ricei*) were previously proposed as "regionally significant species" under the British Columbia Forest Practices Code, the classification was never formalized.

3.5.2 Issues

3.5.2.1 Overview

Issues with aquatic resources are associated with water quality and quantity for both human and aquatic communities, loss or alteration of fish habitat, and increased human access to lakes and streams via roads or trails constructed for seismic activity, exploration drilling, and other more permanent industrial infrastructures.

Water quality can be affected by soil disturbance at industrial sites, leading to release of sediment into surface waters. While Arctic grayling may be adapted to the naturally turbid streams in the eastern portion of the study area, changes in the size distribution of particles or increased concentration of particles caused by industrial disturbance may result in reduced feeding efficiency, decreasing spawning success, and gill abrasion. In reaches of small streams or bog lakes that are not turbid, episodic introduction of suspended solids may substantially reduce survival of fish age classes, and attenuate irradiance, causing a general decline in biological production.

Water quality may also be affected by episodic or more chronic discharge of industrial wastewater. This wastewater may include sewage which can introduce pathogens and nutrients to surface water, which in turn, can lead to, localized eutrophication (excessive biological production caused by high nutrient loading that can be harmful to aquatic communities, including fish). Other chemicals may be released or discharged, and may produce toxic effects in aquatic biota. While it is anticipated that waste is treated before discharge or is contained for disposal at other sites, complete containment and treatment may not always occur. For example, infiltration of contaminated fluids from containment pits or lagoons may flow through porous soils to groundwater, and eventually, to surface waters where anomalous mortalities in critical food webs may occur.

Water quantity may be affected by demand for water for industrial use. For example, water used for hydrostatic testing may lower surface stream flow, and modify wetted usable habitat in downstream reaches, particularly in winter.

Both fisheries habitat and aquatic resources are protected under the *Fisheries Act of Canada* and the *Water Act of British Columbia*. While all industrial activities affecting water quality, fish, and fish habitat are subject to regulation to avoid habitat degradation, multiple small-scale human disturbances can erode habitat and water quality. Interactions between small developments, such as a proliferation of access in adjacent gas fields, may result in synergistic effects. Increased traffic can cause increased soil compaction and associated increases in sediment run-off and impacts to water quality.

The issue of developing access into previously intact wilderness areas is of increasing concern. A prime example of that involves fluvial migratory bull trout during both the pre-spawn staging and spawning periods. In mid- to late-summer and early fall, mature adult bull trout migrate long distances to congregate at selected sites in foothills drainages. During this time, they are particularly vulnerable to exploitation, as many large fish, often in excess of 800 mm in length, may assemble in shallow streams. Under these conditions, even limited illegal angling effort could result in significant impacts to the annual recruitment within a bull trout subpopulation. While aggregations of large, slow-growing bull trout provide a dramatic example of the potential effects of access development, many other fish species are similarly susceptible to over-exploitation of previously remote populations.

In many cases, impacts associated with increased access are not solely derived from industrial actions, but through related activities. For example, closely aligned and linked industrial roads can provide increased access to an area by ATVs or snowmobiles. This can lead to dramatically increased interest in formerly inaccessible areas, which in turn can result in increased pressure on environmental resources, such as local fish populations.

3.5.2.2 Interior Plateau

The issue of particular concern in the Interior Plateau is the sustainability of Arctic grayling. Bull trout distribution is generally restricted to over-wintering of adults in large mainstem rivers.

Numerous sub-populations of Arctic grayling occur throughout the eastern portion of the study area in apparent geographic and genetic isolation from each other and from foothills populations. Grayling populations can occur in accessible tributary drainages that originate on well-drained uplands and provide riffle-pool habitat configurations with gravel/cobble substrates. Portions of the upper Beatton, upper Milligan, upper Chinchaga, upper Kahntah, Trutch, and Klua drainages support such populations. Streams in this portion of the study area have low-to-moderate average gradients, and relatively high concentrations of suspended sediment caused by fast weathering of sedimentary parent materials. Yearling and post-yearling juvenile grayling in plains populations generally make significant upstream feeding movements during the summer, and can be found in abundance at the headwaters of suitable tributary drainages upstream of the distribution limits of other species.

Plateau wetland and muskeg complexes dominate much of the northeast portion of the Interior Plateau. Streams occurring in these areas typically originate on organic peat lands, and are characterized by meandering large-channel morphologies, average gradients less than 0.5%, and substrates composed of fines and organic accumulation. Beaver activity is extensive, with large segments of stream modified into series of dams and impoundments that are interrupted by sections of muskeg seepage and discontinuous channel. These habitats typically have low sensitivity to disturbance due to the dominance of sediment and organic substrates, and extremely low potential for erosion due to low gradient and discharge velocity. Suitability for most fish species is restricted by low habitat diversity, high summer temperatures, low dissolved oxygen levels, absence of winter discharge, and lack of seasonal access. Drainage systems within these muskeg complexes often support resident populations of brook stickleback and finescale dace. Due to their tolerance of high water temperatures and low dissolved oxygen levels, these two species are often extremely abundant and widespread in low-sensitivity, marsh-like habitats where no other fish species are able to survive. They successfully over-winter in beaver impoundments and other small bodies of water where little or no flow is present.

3.5.2.3 Muskwa-Kechika Management Area

Within the MKMA, the issue of particular concern is the sustainability of bull trout. While Arctic grayling distribution spans the width of the entire study area, their presence in the more mountainous MKMA section, including the areas typically occupied by bull trout, is largely restricted to the post-spawning, over-summering of mature adults. Current and historical sampling data and limited radio-telemetry data suggest that adult Arctic grayling in the MKMA portion of the study area spawn in the warmer, more turbid tributaries along the eastern boundary before moving farther west into clearer, cooler, mountain-fed streams and rivers for the summer (T. Euchner, pers. comm.). Rearing juvenile grayling are rarely found in the low-turbidity systems of the mountains and foothills that are frequented by juvenile bull trout.

Bull trout are largely confined to the low-turbidity, moderate-gradient systems that flow east from the Rocky Mountains and Rocky Mountain Foothills to meet the Halfway, Prophet, Muskwa, and Liard Rivers. Streams in this zone typically originate in mountainous areas where comparatively high landform stability and low soil erodability result in low suspended solids concentrations. This relatively clear water provides mature bull trout with the silt-free, gravel substrates required for successful fall spawning and winter incubation.

Following spawning, bull trout eggs incubate in gravel substrates for up to eight months (September-April) before hatching. During this period, redd sites must remain silt-free and receive a constant supply of oxygenated water, regardless of flow conditions. Ground water upwelling within the stream channel may be an important factor in maintaining this consistency. Since these conditions are closely associated with the geology of more mountainous terrain, bull trout distribution does not extend into the eastern portion of the management area, except in the case of adult mainstem over-wintering habitat. Critical spawning habitat for migratory bull trout populations is known to occur in the Graham, Cypress, Chowade, upper Halfway, Besa, Prophet, Muskwa, Gathto, and Tuchodi drainages. Juvenile bull trout (yearling to three-year age classes) appear to disperse widely into small tributary and headwaters habitats within these natal watersheds.

In contrast to portions of the Interior Plateau section of the study area, the exceptionally high recreational values in the MKMA may intensify pressure on local fisheries resources as visitors drawn to the area for hiking and hunting pursue angling as a secondary activity.

Within the study area, the MKMA is of particular value as a recreational area. Activities including hiking, angling, camping, and backcountry cycling may be pursued in a pristine setting. Part of the backcountry experience is the appreciation of clear, cool streams and lakes that are not affected by disturbance. Glacial turbidity is recognized as part of high water quality in the alpine, but turbidity produced from land or industrial disturbance can greatly reduce the aesthetic characteristics of mountainous settings. Hence, an important issue specific to the MKMA is the maintenance of high-quality steams and lakes that are not disturbed by bank or soil instability resulting from industrial activity. The issue here is recognition of high aesthetic values of aquatic systems that inherently demand no effects of land disturbance or industrial wastewater discharge.

3.5.3 Valued Components

During the process of defining issues associated with cumulative impacts to aquatic ecosystems in the study area, several valued ecosystem components were identified (Table 3-2). A number of common themes are evident in the VECs associated with fish. Limiting human access to streams and lakes is a recurring issue in terms of its effect on over-exploitation of bull trout and grayling. Maintenance of physical habitat structure and presence of stable flow of high quality water is also important. While there is an issue of maintaining rearing and spawning habitat, protecting migration routes used by bull trout is of equal importance. Protecting riparian zones along streams and littoral zones around lakes is an issue because of the risk of disturbance to these sites, particularly during oil and gas exploration activity, and forest harvesting.

In selecting specific VECs for the study area, the appropriateness of an individual fish species was determined by identifying the priority of cumulative effects issues, identifying good indicators for these effects, and determining how these effects can be estimated or measured.

Therefore, while a species may be considered regionally significant, if it occurs at low densities or has a restricted distribution, it may not be an appropriate VEC. An example of this selection criterion is chum salmon (*Oncorhynchus keta*), which only occurs at low densities in the Liard River system within the study area (Haas 1998). Without negating the need for conservation measures to protect chum, the species would not meet the criteria of being a readily measurable VEC. McLaren et al. (1998) list several conditions that must be met in selecting wildlife indicator species, including cost-effectiveness in monitoring, and a "reasonable degree of success" in locating the species when sampling.

Table 3-2. Attributes of Aquatic VECs

Issue/VEC	Attributes
Water Quality/Quantity for Human Consumption	• uncontaminated surface and groundwater • stable water supply
Habitat Quality for All Indigenous Fish Species	• unimpeded access for seasonal movements for foraging, overwintering, and spawning • preservation of habitats important to all life-history stages, including upper-reach, juvenile rearing habitats, and mainstem and large-channel over-wintering habitats (e.g., beaver impounded channels that support over-wintering populations of brook stickleback and finescale dace) • maintenance of riparian, instream, and littoral vegetation • maintenance of habitat structure and complexity to meet cover, foraging, and spawning requirements (e.g., large woody debris, boulders, and bedrock) • preservation of stable stream flow regimes, including avoidance of activities that lead to altered hydrology and stream channel
Bull Trout Distribution and Abundance	• unimpeded access for seasonal movements for foraging, overwintering, and spawning • habitat structure to meet cover, foraging, and spawning requirements (e.g., large woody debris, boulders, and bedrock) • stable upper-reach rearing habitats • isolated resident populations in upper portions of watershed • protection from exploitation during vulnerable periods • water quality and quantity to support over-wintering eggs • cold-water species (maintenance of cooler stream temperatures reduces competition with warmer water species (e.g., rainbow trout (*Oncorhynchus mykiss*))
Arctic Grayling Distribution and Abundance	• unimpeded access for seasonal movements for foraging, overwintering, and spawning • habitat structure to meet cover, foraging, and spawning requirements (e.g., large woody debris, boulders, and bedrock) • upper-reach rearing habitats • protection from over-exploitation, particularly during vulnerable periods • sensitivity to water quality (e.g., visual foraging, incubation of eggs)
Critical Habitat Areas	• critical spawning areas for both fluvial and lacustrine spawners • holding areas where aggregations of fish species are found on a seasonal basis
Intact Riparian Communities	• riparian vegetation important for regulating stream temperature, flow regimes, and sediment input, also a source of nutrients • habitat structure and complexity • stable aquatic and terrestrial invertebrate community

The same principle was applied to the selection of representative fish species for this project; those species that occur in sufficient numbers over a large portion of the study area were chosen over species with restricted or localized distribution. This criterion eliminated numerous species, including chum salmon, as potential VECs. In also identifying "habitat quality for all indigenous fish species" as a VEC, it was assumed that the life requisites of other species would be addressed.

Bull trout and Arctic grayling were recognized as VECs in the study area (Figure 3-15 provides observations). While these two species are important sport fish, protection of their habitat indirectly assists in protecting many other indigenous species. Mature fish of both species commonly over-winter in the mainstems of large rivers and the lower reaches of significant tributaries, and they undertake upstream movements to spawning or summering habitats. While both the spring-spawning grayling and fall-spawning bull trout have stringent requirements for water quality, bull trout eggs require stable high quality water flow for a prolonged winter period. Rearing juvenile bull trout and grayling may penetrate the extreme headwaters of their natal tributary systems during summer feeding movements, and are typically present in small streams upstream of the distribution limits of other fish species. Young-of-the-year and yearling bull trout and Arctic grayling may successfully over-winter in relatively small tributary streams where they often survive despite marginal discharge and apparent "frozen down" conditions. These upper-reach, juvenile rearing habitats generally have high potential to be affected by industrial activity, including petroleum exploration and production, forest harvesting, and associated access development.

Cannings and Ptolemy (1998) note that newly emerged grayling fry are susceptible to high stream discharge, therefore, side channel and stream margin habitats are important until the fry have attained sufficient size and strength to move into faster-flowing water. Adults of both species are vulnerable to sudden increases in exploitation as a result of improved human access to summer rearing habitats, in the case of Arctic grayling, and fall staging and spawning habitat, in the case of bull trout. The migratory behaviour of both species demands maintenance of stream networks and access, which also benefits the movements of other species.

As well as being blue-listed by the BC Conservation Data Centre, bull trout are classified as an "identified wildlife species" (IWMS 1999). While only the isolated Williston Watershed population of Arctic grayling is red-listed, on a regional scale, the species is identified by Haas (1998) as requiring "special forestry consideration" since they are highly sensitive to angling pressure and water quality. The Fort St. John LRMP makes specific reference to grayling and bull trout, suggesting they "appear to be diminishing in presence and population size in many watersheds" (Fort St. John LRMP 1997).

3.5.4 Hot Spots

Hot spot polygons represent areas that currently have increased potential for conflict between industrial development and sensitive aquatic resources (Figure 3-16), and do not assume the absence of concern elsewhere. Hot spots derived from Arctic grayling distribution dominate upland portions of the Interior Plateau, while hot spots associated with bull trout presence occur in mountain and foothills terrain in the southwest portion of the study area.

3.6 Vegetation

3.6.1 Setting

The Interior Plateau is almost exclusively covered by the Boreal White and Black Spruce (BWBS) biogeoclimatic (BEC) zone (Meidinger and Pojar 1991), with the Spruce-Willow-Birch (SWB) and Engelmann Spruce-Subalpine Fir (ESSF) BEC zones found at elevations above 1300 m (Delong, Annas and Stewart 1991) (Figure 3-17). Extensive, well-drained forests of the plateau are characterized by frequent fires that result in a matrix of mixed coniferous and deciduous species at various successional stages. Dense black spruce dominates the poorly-drained muskeg-like portions of the BWBS zone. The southern portion of the region has well-drained alluvial sites that are productive from a forest or agriculture perspective. Extensive networks of wetlands and shallow lakes connected by riparian areas and floodplains are common high-value components of the landscape. Engelmann spruce and subalpine fir forests are found at higher elevations (up to 1700 m) in the southern portion of the plateau, but are replaced by the Spruce-Willow-Birch zone at similar elevations in northern regions of the plateau.

Due to its topography, the MKMA is dominated by the Spruce-Willow-Birch (SWB) BEC zone. White spruce and subalpine fir are the dominant species of this zone. The Boreal White and Black Spruce BEC zone is found in the lower elevation valleys, while the Alpine Tundra zone occurs at higher elevations of the management area.

Boreal White and Black Spruce zone

Major trees species in the BWBS include white spruce, trembling aspen, lodgepole pine, black spruce, balsam poplar, larch, tamarack, subalpine fir, common paper birch and Alaska paper birch (Delong, Annas and Stewart 1991).

Dry sites (BWBS dk) are dominated by white spruce and lodgepole pine with soopolallie or soapberry in the shrub layer, and bastard toad-flax in the herb layer. The moister subzone (BWBS mw) commonly has white spruce, trembling aspen and lodgepole pine in the overstory. Understory species which distinguish this subzone from others include creamy peavine, tall bluebells, northern bedstraw and common miterwort. The wet, cool BWBS wk subzone is differentiated from the other subzones by the presence of subalpine fir and black huckleberry (Delong, Annas and Stewart 1991).

Spruce-Willow-Birch zone

White spruce and subalpine fir dominate lower elevations of this poorly studied zone. No subzones are distinguished. Pine and aspen occur in valley bottoms and on lower slopes, while scrub birch and several willow species dominate poor nutrient and moderate nutrient upper elevation sites, respectively (Pojar and Stewart 1991).

Engelmann Spruce-Subalpine Fir zone

The provincial extent and regional diversity of the ESSF zone, which is comprised of fifteen forested and fifteen parkland subzones, makes it impossible to easily summarize its characteristic vegetation. In general, ESSF forests are dominated by Engelmann spruce and subalpine fir except where lodgepole pine has established after fire. ESSF parkland can be comprised mainly of heathers in the high elevations with late snow melt, while more sheltered, moist subalpine meadows can be dominated by herbaceous species such as sitka valerian, Indian hellebore, arrow-leaved groundsel, subalpine daisy and arctic lupine (Coupe, Stewart and Wikeem 1991).

3.6.2 Issues

Oil and Gas

In general, oil and gas development may have substantial effects on vegetation in the region. Direct effects occur in the form of plant structural and successional changes due to clearing, and to topography changes associated with the construction of seismic lines, well pads, production facilities, infrastructures, and pipelines. Indirect effects can include successional changes, or reduced plant health due to increased soil acidity, drainage pattern changes, and industry-related air emissions.

Seismic lines are long, linear disturbances that affect plant communities due to clearing and habitat fragmentation. Severe damage to soils and vegetation allows for the introduction of alien or noxious species as the plant community is shifted to an earlier successional stage. If seismic lines are put in through wetlands, hydrological changes may occur, and the ratio of wetlands to uplands may be altered due to vegetation clearing.

Road construction, site clearing, camp construction, and well site flaring are the primary activities undertaken during exploration drilling. Their effects on vegetation are similar to those of seismic line development except for the linear nature of seismic lines. Additional impacts on vegetation from exploration drilling includes deteriorating plant health from air-borne pollution, road salting during the winter, and dust deposits from road traffic.

Hydro-electric

Vegetation can be severely affected by hydro developments, particularly dam-associated flooding. Additional effects are incurred through the construction of roads and infrastructures needed to maintain hydro facilities, and through changes in water levels and flows due to reservoir operations. Changes in the timing and availability of water can affect plant community composition, or cause shifts to a different site-series association.

Mining

Development of access routes to large mining operations can have considerable impacts on vegetation due to clearing and habitat fragmentation. Open pit mining tailing depositions can have severe impacts on vegetation in the development footprint, but will have a relatively minor effect compared to strip-mining operations.

Forestry

The forest industry has a major influence over the land-base of the region, hence the impacts of forestry operations can be severe, especially if there is little or no co-ordination among tenure holders. Forestry-related impacts on vegetation include habitat fragmentation, the creation of edge-effects due to cutblock development, and the creation of patch sizes that are inconsistent with the natural disturbance patterns of the region. Additionally, vegetation structure, function, and composition are affected by harvesting activities, while early successional vegetation patterns dominate in cut-overs.

Transportation Development, Repair, and Maintenance

Roads can effectively be hard boundaries to plant distributions, which can lead to potential isolation of populations. Long, linear, main roads, and resource trunk roads and spurs are ubiquitous fragmenting agents on the landscape. Roads increasingly isolate patches of remaining forests, and can cause changes in forest vegetation due to increased light intrusion, increased ruderal species presence, and reduced microsite effects that extend into nearby forests (i.e., cause edge effects). Additionally, grading, dust deposition and salt application commensurate with road maintenance and repair can affect roadside vegetation by reducing photosynthetic capability or by removing salt-intolerant species. These effects can also facilitate the incursion of noxious weeds and alien species into previously pristine areas. Herbicide and agro-seed applications on road and rail RoWs are particularly damaging to vegetation.

Agricultural Land Conversion and Urban Sprawl

Agriculture and urban development have severe and often permanent effects on vegetation as land conversion removes all or most of the existing natural vegetation. Agriculture fields and urban landscaping projects can also be sources of escaped plant species that result in noxious weed invasions of nearby areas. Additionally, agricultural crop and residential yard management can have downstream effects on water and soil due to water use, and herbicide and fertilizer applications.

Tourism and Recreational Activities

The current effects of tourism and recreational development in the region are low, but have potential to become greater in the future. New roads and infrastructures are normal precursors to the development of facilities such as fishing or ski lodges, and can cause losses of native vegetation due to clearing. Additional and increasing impacts from ATV or other off-road use can inhibit natural vegetation regeneration, and can keep RoWs open rather than allowing them to re-vegetate over time. Increased access to remote areas can also increase the risk of human-caused forest fires.

3.6.3 Valued Components

The identification of vegetation VECs (Figure 3-18) was based on Broad Ecosystem Unit (BEU) types and structural stage values from the 1:250,000 Broad Ecosystem Inventory (BEI) (RIC 1998). There are 33 BEU types within the study area. To simplify VEC selection at this scale, these BEU types were grouped into six vegetation types: forests greater than 140 years old ('old-growth'); forests 140 years old or less; alpine; wetlands; parkland; and non-vegetated (e.g., cultivated field, rock, gravel bar).

Old-growth forests, wetlands[3], and any regionally rare BEU types were considered to be VECs because they may be susceptible to fragmentation or complete removal, and may contain regionally unique plants species. Additionally, old-growth forests were considered to be a VEC because they are comprised of unique, late succession plant community types, and typically provide high value wildlife habitat and timber harvesting opportunities. Old-growth boreal forests are also considered to be important carbon sinks. Wetland plant communities were considered to be a VEC because they may contain rare plant species, and are highly sensitive and susceptible to disturbance due to recreational and resource use activities.

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[3] Although, large areas of wetlands occur east of the Alaska Highway, wetlands are sensitive ecosystems that are highly susceptible to disturbance. The presence of large wetland areas in some parts of the region does not negate this sensitivity.

3.6.4 Hot Spots

Vegetation hot spots (Figure 3-19) tend to be concentrated along linear developments such as highways and rail lines. Most of these hot spots occur within the Interior Plateau; the greatest concentration of those in the Taiga Plains. The hot spots here tend to be concentrated along Highways 77 and 97, and along the rail line that follows the Fort Nelson River. A large hot spot area on the Etsho Plateau is associated with concentrated block developments (i.e., well sites). Within the Northern Boreal Mountains, hot spots occur mainly around the Liard River and on the southern portion of the Liard Plateau. In the southern portion of the Interior Plateau, hot spots tend to be concentrated along the eastern and western portions of the Boreal Plains. Both of these areas are highly disturbed. The lack of hot spots in the Fort St. John region is likely a result of conversion of native vegetation to agricultural crop development.

3.7 Wildlife

3.7.1 Setting

The study area supports a large number of resident wildlife species, and includes the migratory routes of numerous bird species. The large mammals of the region have received considerable attention with respect to inventory, and in more recent years, research efforts have been initiated on topics such as habitat use patterns and predator-prey dynamics. The large size and general remoteness of the study area, however, means that for many species, in particular those that are cryptic or of low economic profile, data on distribution, abundance, and ecology are limited.

Issues for key wildlife that are considered to be of concern with respect to cumulative effects in the study area are provided in Tables 3-3 (mammals) and 3-4 (birds). Selection of these species is based on federal (COSEWIC) or provincial status designations, or economic and/or public profile value. Information on conservation status, study area distribution and abundance, and socio-economic value is also provided. The key bird species group was further defined by including only species known to breed in the study area. No amphibians or reptiles met the criteria for key species in this region. Not included for consideration as key species were insects, although it is important to note that there are many blue-listed species and some red-listed species in the study area.

Table 3-3. Key Wildlife (Mammals)

Key Species	Conservation Status	Study Area Distribution and Abundance	Socio-economic Values
Woodland Caribou	Provincial: blue (boreal and northern mountain populations) Federal: boreal population – threatened; mountain population – special concern	Found throughout the study area at low densities, or in small isolated herds[1]	Hunting, wildlife viewing
Wood Bison	Provincial: red Federal: threatened	MKMA: not present Interior Plateau: small reintroduced populations found: a) on west side of the Liard River near the NWT border south toward the confluence of the Liard and Crow Rivers; b) on north side of Liard River; c) in the Etthithun Lake-Kahntah River headwaters area; and d) extending into BC from a herd in the Hay-Zama region of northwestern Alberta[2]	Wildlife viewing
Plains Bison[3]	Provincial: blue Federal: not listed	One population on the boundary of the MKMA and the Interior Plateau. Found west of Sikanni Chief and Pink Mountain, in an area extending from the south side of the Halfway River to just north of Trimble Lake and the Sikanni Chief River[4]	Hunting, wildlife viewing
Moose	Provincial: yellow	MKMA: generally low to moderate densities[5] Interior Plateau: generally low density in extreme northeast, moderate to high densities elsewhere[2]	Hunting, wildlife viewing
Stone's Sheep	Provincial: yellow	MKMA: throughout Interior Plateau: small herds found along cliff banks of lower sections of the Buckinghorse and Sikanni Chief Rivers and adjacent tributaries.[6] Also found in similar habitats in the Liard drainage[2]	Hunting, wildlife viewing

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[1] Shackleton 1999, Dzus 2001

[2] Shackleton 1999, Harper et al. 2000

[3] Introduced

[4] Shackleton 1999

[5] Shackleton 1999

[6] MacGregor 1977, Hebert and Smith 1986, Poole and Fear 1998

Key Species	Conservation Status	Study Area Distribution and Abundance	Socio-economic Values
Mountain Goat	Provincial: yellow	MKMA: throughout Interior Plateau: small herds found along cliff banks of lower sections of the Buckinghorse, Sikanni Chief and Boat Rivers and adjacent tributaries[2]	Hunting, wildlife viewing
Rocky Mountain Elk	Provincial: yellow	Widely distributed in Peace River area – as far north as the Liard Plateau and south along the Kechika valley and west to headwaters of the Major Hart and Turnagain Rivers[2] Densities generally sparse throughout, but there are a few high density areas near Fort St. John and in the Prophet River vicinity[2]	Hunting, wildlife viewing
White-tailed Deer	Provincial: yellow	MKMA: marginal along eastern boundary; low density[2] Interior Plateau: low density along Fort Nelson and Peace Rivers and their tributaries to as far north as the Liard River[2]	Hunting, wildlife viewing
Rocky Mountain Mule Deer	Provincial: yellow	Sparsely distributed up into the Liard River area and east through the Peace area to the Alberta border[2]	Hunting, wildlife viewing
Grizzly Bear	Provincial: blue Federal: special concern	MKMA: throughout; low density Interior Plateau: sparsely distributed in the foothills and across the border into Alberta. Densities in this zone range from 104 to 420 km^2 per bear [7]	Hunting, wildlife viewing
Black Bear	Provincial: yellow Federal: not at risk	Throughout; low to moderate abundance	Hunting, trapping, wildlife viewing
Wolf	Provincial: yellow	Throughout	Trapping, hunting, wildlife viewing
Wolverine	Provincial: blue Federal: special concern (western population)	Throughout; low density	Trapping, hunting
Lynx	Provincial: yellow Federal: not at risk	Throughout; abundance variable	Trapping, hunting
Fisher	Provincial: blue	Throughout; uncommon	Trapping
Marten	Provincial: yellow	Throughout	Trapping

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[7] Banci 1991

Key Species	Conservation Status	Study Area Distribution and Abundance	Socio-economic Values
Aquatic Furbearers (beaver, muskrat)	Provincial: yellow	Throughout; abundance variable	Trapping
Red Squirrel	Provincial: yellow	Throughout; abundance variable	Trapping
Snowshoe Hare	Provincial: yellow	Throughout; abundance variable	Trapping, hunting,
Northern Long-eared Bat	Provincial: blue	Western extreme of range. Found at sites in the Prophet, Peace and Liard River areas[8]. More common in northern BC than previously thought[9]	

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[8] Nagorsen and Brigham 1993, Crampton et al. 1997, Cannings et al. 1999

[9] Wilkinson et al. 1999, Vonhof and Wilkinson 1999

Table 3-4. Key Wildlife (Breeding Birds)

Key Species	Conservation Status	Study Area Breeding Distribution and Abundance[10]	Socio-economic Values
Short-eared Owl	Provincial: blue Federal: special concern	MKMA: unlikely Interior Plateau: possible	Wildlife viewing
Peregrine Falcon (*anatum* subspecies)	Provincial: red Federal: threatened	MKMA: unknown Interior Plateau: little information; a few breeding records exist	Wildlife viewing
Bald Eagle	Provincial: yellow Federal: not at risk	Local breeder throughout	Wildlife viewing
Ruffed Grouse	Provincial: yellow	Throughout	Hunting, wildlife viewing
LeConte's Sparrow	Provincial: blue	MKMA: unlikely Interior Plateau: small numbers – most common in Boreal Plains; few breeding records	Wildlife viewing
Nelson's Sharp-tailed Sparrow	Provincial: blue Federal: not at risk	MKMA: unlikely Interior Plateau: little known, most common in Boreal Plains; few breeding records	Wildlife viewing
Bay-breasted Warbler	Provincial: red	MKMA: possibly in foothills Interior Plateau: small numbers – most common in Boreal Plains; few breeding records	Wildlife viewing
Cape May Warbler	Provincial: red	MKMA: possibly in foothills Interior Plateau: throughout; most common in Taiga Plains; few breeding records	Wildlife viewing
Black-throated Green Warbler	Provincial: blue	MKMA: possibly along eastern slope Interior Plateau: likely throughout, most common in Boreal Plains; few breeding records	Wildlife viewing
Canada Warbler	Provincial: blue	MKMA: unlikely Interior Plateau: may be more abundant than thought, most common in Boreal Plains; few breeding records	Wildlife viewing

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[10] Campbell et al. 1990a, Campbell et al. 1990b, Campbell et al. 1997, Campbell et al. 2001

Key Species	Conservation Status	Study Area Breeding Distribution and Abundance[10]	Socio-economic Values
Connecticut Warbler	Provincial: red	MKMA: unlikely Interior Plateau: small and localized populations, most common in Boreal Plains; few breeding records	Wildlife viewing
Philadelphia Vireo	Provincial: blue	MKMA: unlikely Interior Plateau: likely more widespread than is known, most common in Boreal Plains; few breeding records	Wildlife viewing
Sandhill Crane	Provincial: blue Federal: not at risk	MKMA: does not breed here Interior Plateau: small numbers breed near Fort Nelson	Wildlife viewing
Upland Sandpiper	Provincial: red	MKMA: unlikely Interior Plateau: two breeding records in fallow agricultural fields in the Fort St. John area	Wildlife viewing
Trumpeter Swan	Provincial: blue Federal: not at risk	MKMA: unlikely Interior Plateau: local but widespread breeder	Wildlife viewing
Canada Goose	Provincial: yellow	Throughout	Hunting, wildlife viewing
Mallard	Provincial: yellow	Throughout	Hunting, wildlife viewing
Surf Scoter	Provincial: blue	MKMA: unlikely Interior Plateau: occasional	Wildlife viewing

3.7.2 Issues

The oil and gas exploration and development activities which are generally considered to have the most significant effects on wildlife are: seismic line development; temporary and permanent access road construction; camp construction and operation; drill site activity and operation; well site and production plant activity and operation; and pipeline construction and operation. The primary cumulative effects issues for wildlife associated with these activities are:

- habitat loss and fragmentation due to vegetation clearing and alteration of seral structure (post-reclamation or site decommissioning);
- reduced effectiveness of available habitat due to sensory disturbance (e.g., vehicle traffic, helicopter overflights, production plant operation);
- increased direct mortality due to increased human (hunters and poachers) and predator access; destruction of nests, dens or hibernacula (during construction phase); potential health impacts associated with project-related contaminants; collisions with vehicles; and problem wildlife incidents (associated with camps); and
- disruption of movements due to vegetation clearing and increased human and predator access.

Additionally, activities in other sectors may contribute to the cumulative effects from oil and gas exploration and development. These activities may include hydroelectric development; mining; forestry; transportation corridor development, repair and maintenance; agricultural land development; hunting; urban sprawl; and tourism and recreation. Of these, forestry and hunting are the most likely activities to result in impacts that contribute to those from the oil and gas sector due to the nature of their effects and the overlapping geographic areas of interest.

Species-specific effects of oil and gas exploration and development are described below for key species. In general, for all these species, there is a lack of information on the impacts of oil and gas exploration and development as it occurs in the study area.

3.7.2.1 Ungulates

Woodland Caribou (*Rangifer tarandus caribou*): Woodland caribou may be exposed to increased wolf predation as a result of industry-related disturbances, not only because of facilitated predator access along linear corridors, but also because an increase in early successional habitats supports higher densities of moose and deer, which in turn, support an increased density of wolves (Rettie and Messier 1998, Rettie 1998). Caribou tend to avoid roads and seismic lines (Jalkotzy et al. 1997, Dyer 1999). This avoidance seems to be greatest in late winter (Dyer 1999). Buried pipeline RoWs did not appear to be a barrier to caribou movements, although some avoidance was observed (Jalkotzy et al. 1997). Caribou avoided recently fragmented (by logging) areas in west central Alberta by average distances of 1.2 km (Smith et al. 2000). Much of the work examining the impacts of oil and gas development on barren-ground caribou may also have application to the woodland caribou.

Wood Bison (*Bison bison athabascae*): Wood bison are known to congregate along RoWs that are seeded with sedges (Gates et al. 2001). Oil and gas development can increase meadow and grassland habitat, and it has been suggested that the recovery of bison populations may be facilitated by these activities (Gates et al. 2001). There does not yet appear to be any studies that have specifically addressed the impacts of oil and gas exploration and production on this species (Carbyn et al. 1998), although disturbance effects may be similar to those noted for other ungulates. A trial project is underway to establish a population of wood bison on an oil sands lease area north of Fort McMurray (Gates et al. 2001).

Plains Bison (*Bison bison bison*): The plains bison population was introduced to the study area when individuals escaped from a farm in the Pink Mountain area in the early 1970s (Shackleton 1999, MELP 2000). This population is a potential threat to the genetic integrity of wood bison in the region (Shackleton 1999). There is no information available on the impacts of oil and gas development on this species, although disturbance effects are likely similar to those observed for wood bison and other ungulates. For example, the risk of wolf predation and unregulated harvest may increase with increased road access into the bison's range.

Moose (*Alces alces*): Moose habitat use near roads associated with oil and gas development may be significantly reduced (Jalkotzy et al. 1997). In central Alberta, moose were located farther from roads than expected between November and January, and they avoided well-traveled roads approximately one-third more often than less-traveled roads (Rolley and Keith 1980). Linear corridors have also been shown to increase wolf predation on moose (James 1999). Alternately, these developments may sometimes enhance moose habitat as linear corridors through a closed forest will open the canopy, create edges, encourage shrub growth, and facilitate moose movements (Jalkotzy et al. 1997). Several studies have found that pipelines affect moose movement patterns. Buried pipelines without berms were not a barrier; however, elevated pipelines or berms did result in deflection or avoidance (Jalkotzy et al. 1997). Other factors that might influence moose crossings of pipelines include snow accumulation and clearing; human activity; and sex and reproductive status (Fraker and Green 1994).

Stone's Sheep (*Ovis dalli stonei*): Habitat fragmentation and increased road access might affect Stone's sheep, but there is little specific information available for this species[1] (Paquet and Demarchi 1999). The small riverside populations outside the MKMA are potentially vulnerable to habitat disturbance and hunting pressure because of limited escape terrain and ease of human access (Poole and Fear 1998). Studies of disturbance effects on Dall's sheep, mountain goats, and bighorn sheep may be applicable to Stone's sheep (Paquet and Demarchi 1999).

Mountain Goat (*Oreamnos americanus*): Mountain goats seem to be particularly susceptible to disturbance by irregular loud noises, industrial activities, road construction and traffic, snowmobiles, and low-flying aircraft, particularly helicopters (Pendergast and Bindernagel 1977, Foster and Rahs 1983, Nietfeld et al. 1984, Singer and Doherty 1985, Penner 1988, Côté 1996). Adverse reactions to helicopters can affect a goat's physiological condition (Côté 1996), and may indirectly affect survival and reproduction (Joslin 1986). Close approaches by a helicopter can also result in injury or death on steep terrain (Côté 1996). Habituation to disturbance appears most likely when the sources of disturbance are localized and highly predictable (Penner 1988). Goats may show greater tolerance to road traffic and humans on foot during summer than in winter (Benzon and Rice 1987). Seismic lines running along the top of cliffs occupied by goats could facilitate access by wolves, and thus, increase predation rates (Seip and Cichowski 1996). As noted for Stone's sheep, small riverside populations outside the MKMA may be vulnerable to habitat disturbance and hunting pressure because of limited escape terrain and ease of human access (Poole and Fear 1998).

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[1] Anecdotal information provided by guide outfitters at pre-tenure plan workshops for the MKMA have suggested that Stone's sheep are very susceptible to disturbance from access and human activity in a manner similar to mountain goats.

Rocky Mountain Elk (*Cervus elaphus nelsoni*): Elk have been shown to avoid roads in many areas (Ferguson and Keith 1982). A study of the effects of an oil well on elk in Montana suggested that the animals compensated for site-specific environmental disturbance by shifting their range use, activity centres, and habitat use, rather than by abandoning their range (Van Dyke and Klein 1996). Behavioural changes designed to avoid disturbance may continue even after the disturbance has been terminated (Van Dyke and Klein 1996).

White-tailed Deer *(Odocoileus virginianus)*: Although there does not appear to be any specific information on the effects of oil and gas exploration and development on the white-tailed deer, it is likely that wolf predation risk would increase. The white-tailed deer may adapt to roads by avoiding nearby habitats where traffic noise inhibits predator detection, and by selecting advantageous routes and times to cross roads (Forman and Deblinger 2000). This species may accommodate some level of human disturbance on the ground (e.g., Kernohan et al. 1996); however, physiological disturbance effects of snowmobiles have been demonstrated for this species (Moen et al. 1982), but the impacts of this activity on habitat use can be variable (Richens and Lavigne 1978). The white-tailed deer is expanding its range into the northeast perhaps partly as a result of increased deforestation and agricultural development (Shackleton 1999).

Rocky Mountain Mule Deer (*Odocoileus hemionus hemionus*): Roads generally decrease mule deer habitat value and can disrupt their normal migratory and daily travel routes (Wallmo 1978, Towry 1984). Foraging opportunities along roadsides, and salt on highways often attract deer, and may result in increased mortality (Wallmo 1978). Mule deer reproduction decreased significantly in the year following an experiment on ATV harassment (Yarmoloy 1983). Habituation to some industrial developments may occur. For example, mule deer passed under a coal conveyor when adequate clearance was available, regardless of whether the belt was active or not (Greenwood and Dalton 1984).

3.7.2.2 Large Carnivores

Grizzly Bear (*Ursus arctos*): Grizzly bears are known to be affected by human and industrial activities. High levels of human activity may lead to abandonment of prime habitat, or alteration of behaviour (e.g., increased nocturnal activity), or may act as a movement barrier (Hamer et al. 1977, McLellan and Shackleton 1989, Gibeau and Herrero 1998). Females with young may be particularly susceptible (Interagency Grizzly Bear Committee 1987). Grizzly bears avoided habitats within 100 m of roads, regardless of traffic volume, in a region of southern BC that was under oil development (McLellan and Shacketon 1989). In contrast, some bears were attracted to linear corridors in the Bow River valley, apparently because of the abundance of berry-producing shrubs along the RoWs (Gibeau and Herrero 1998). The location and protection of denning sites has been noted as a primary concern with respect to oil and gas development in grizzly bear habitat (Antoniuk 1994). Helicopter overflights may be a significant problem during den entrance and exit periods (fall and spring, respectively) when bears are in relatively exposed habitats. Oil and gas activities can also lead to direct bear-human interactions. The problems that arise when bears become habituated to human food sources, such as camp garbage, are well-documented (Carr 1989, Herrero 1989, 1985, Craighead and Craighead 1970, Dalle-Molle and Van Horn 1989). Additionally, roads facilitate access by poachers and hunters, the grizzly bear's only predators.

Black Bear (*Ursus americanus*): Generally, black bears show greater adaptability to, and tolerance for, human activities than the grizzly bear, although industrial development can still result in the direct loss or alteration of black bear habitat. Roads and trails associated with resource development activities may be avoided by black bears because of sensory disturbance or increased hunting pressure. Their home ranges have been known to conform to the artificial boundaries imposed by roads and highways (Manville 1983), although bears may also readily cross these same features. Black bears appear to be sensitive to disturbance during the pre-denning phase (Tietje and Ruff 1980, Manville 1983, Horejsi and Raine 1983). This species can also become a serious management problem if it becomes habituated to human food sources (e.g., camp garbage).

Wolf (*Canis lupus*): Wolves generally avoid areas with high road densities, and high levels of human activity (e.g., traffic) and related disturbances (Mech et al. 1988, Thurber et al. 1994, Jalkotzy et al. 1997, Westworth Environmental Associates Ltd. 1998, James and Stuart-Smith 2000). Increased wolf mortality due to vehicle collisions and poaching occurs in areas with high road densities (Mech et al. 1988, Thurber et al. 1994, Jalkotzy et al. 1997, James and Stuart-Smith 2000). Human disturbance (foot traffic, aircraft, vehicles) may result in abandonment of natal dens (Ballard et al. 1987, Jalkotzy et al. 1997). People on foot can disturb wolves up to a distance of 0.8 km, although tolerance varies among packs (Thiel et al. 1998). Unused or rarely used linear corridors (e.g., pipelines, roads, powerlines) provide easy travel routes for wolves and access to ungulate prey (Jalkotzy et al. 1997, Westworth Environmental Associates Ltd. 1998, James and Stuart-Smith 2000).

Wolverine (*Gulo gulo*): Wolverines appear to avoid human settlements (Banci 1994); however, they have been observed feeding in garbage dumps, and are known to occur in the logged forests of the sub-boreal interior of B.C., and in habitats where seismic lines are common (Banci 1994). Wolverines may be particularly sensitive to human disturbance when they have kits. Females have been known to move their young to less secure dens to avoid human contact (Banci 1994, Pulliainen 1968). Human development and major access routes (highways) may function as dispersal barriers (Krebs and Lewis 1999; Kyle and Strobeck 2001). Determining the impacts of agriculture, forestry, and energy development on wolverines is confounded by the effects of mortality from hunting, trapping, and poisoning (Dauphiné 1989), and by the lack of information on the species habitat requirements (Banci 1994). The persistence of wolverine populations appears to depend on the existence of large, unroaded, wilderness refugia (e.g., National Parks) where human activity is limited (Hornocker and Hash 1981, Hatler 1989, Banci 1994, Krebs and Lewis 1999).

3.7.2.3 Furbearers

Lynx (*Lynx canadensis*): There is some evidence that roads may influence lynx movements (Clayton 2000), but there is also evidence that they will cross highways and openings (Mowat et al. 2000), perhaps depending on width and availability of cover (Todd 1985). Lynx occasionally hunt or travel along seismic lines (Riewe 1980), and have been reported to follow road edges and forest trails for considerable distances (Parker 1981). In northern Canada and Alaska, anecdotal evidence suggests that lynx will tolerate moderate levels of snowmobile traffic through their home ranges (Mowat et al. 2000). In western Alberta, lynx frequently crossed a pipeline RoW prior to construction, but almost completely avoided the area during the construction period (Morgantini 1984). Lynx have been found to persist mainly in isolated, untrapped refugia during low points in the population cycle, and increased access or other disturbances to such areas could negatively affect subsequent population recovery (Todd 1983, 1985). Habitat fragmentation tends to increase competition between lynx and generalist predators, such as coyotes and cougars (Buskirk et al. 2000).

Fisher (*Martes pennanti*): Fishers have been shown to seldom travel along roads or powerline RoWs (Johnson and Todd 1985). While they apparently avoid linear corridors during construction activities, they may not significantly shift their territories in response to post-construction levels of activity (Morgantini 1984, Eccles and Duncan 1987). Fishers are considered curious by nature, but their usual reaction to the presence of humans seems to be avoidance (Jalkotzy et al. 1997). However, Johnson and Todd (1985) suggest that the rarity of sightings may actually be the result of their relative scarcity rather than actual avoidance behaviour. Little is known about the impacts of forest removal activities, such as seismic clearings, on the fisher's use of forest edges (Fenske-Crawford and Niemi 1997).

Marten (*Martes americana*): Marten are known to be sensitive to intense human disturbance, but they may be able to adapt to less intense disturbances (e.g., selective logging) (Koehler et al. 1975, Soutière 1979). Many studies, including one in the Prophet River area (Poole and Stanley 1998), have reported that marten respond negatively to habitat fragmentation (e.g., Steventon and Major 1982, Hargis et al. 1999, Potvin et al. 1999). No consistent response to linear development has been demonstrated, but there is some evidence that crossings are generally avoided or attempted unsuccessfully (Eccles and Duncan 1986, Jalkotzy et al. 1997, Robitaille and Aubry 1999). Several studies have reported that marten occasionally cross large openings (e.g., 50 to 200 m), although they generally will stop only in areas with cover (Koehler et al. 1975, Soutière 1979, Hargis and McCullough 1984).

Aquatic Furbearers: There has been little study of the impacts of oil and gas exploration and production on the beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*). Potential impacts on these species might be expected if there were localized hydrological regimes alterations (e.g., artificial damming). Research on the Mackenzie Delta found that seismic activity resulted in short term reductions in muskrat activity levels, but apparently did not affect daily activity patterns, number of daily movements, or use of houses (Westworth 1980). Habitat alterations that result in deciduous regeneration can produce high quality beaver habitat (Slough and Sadleir 1977, Poole 1998, Slough 1988, Barnes and Mallik 2001).

Red Squirrel (*Tamiasciurus hudsonicus*): The red squirrel does not seem particularly sensitive to disturbance. The species did not avoid forested habitats adjacent to the Norman Wells-Zama pipeline in the NWT (Eccles and Duncan 1987), and it was found to be abundant in forests fragmented by agriculture in north central Saskatchewan, although it was less abundant in small fragments (Bayne and Hobson 2000). Any potential impacts would be most severe during periods of poor cone production.

Snowshoe Hare (*Lepus americanus*): Snowshoe hares do not appear to be particularly sensitive to disturbance, provided their requirement for dense cover is met (e.g., Thompson et al. 1989). Studies in Alberta (Windberg and Keith 1978) and Wisconsin (Keith et al. 1993) suggest that hares persist in fragmented habitats, although survival may be lower in very small patches (e.g., 5-15 ha). In a study along the Norman Wells-Zama pipeline in the NWT, there was less use of the pipeline clearing, but no consistent use pattern (less or more) for the undisturbed habitat adjacent to the clearing (Eccles and Duncan 1987). Since predation is the most important source of mortality among snowshoe hares (Hodges 2000), and predation risk may have indirect effects on hare reproduction and survival (Hik 1995, Boonstra et al. 1998), any development activities that increase predator numbers or access may have important consequences for hare populations.

3.7.2.4 Small Mammals

Northern Long-Eared Myotis (*Myotis septentrionalis*): This bat is known to be particularly vulnerable to disturbance at the juvenile stage and during the winter (Caceres and Pybus 1997). During hibernation, disturbance effects may deplete this species' limited energy stores (Speakman et al. 1991, Thomas 1995, Caceres and Pybus 1997), and any changes to the internal environment of a hibernaculum may result in its abandonment (Caceres and Pybus 1997). The ecology of this species is little known (Caceres and Pybus 1997), and there is no research available regarding potential impacts of oil and gas exploration and development.

3.7.2.5 Birds

Raptors and Owls

Three key species were identified for this group: Short-eared Owl (*Asio flammeus*), Peregrine Falcon (*Falco peregrinus anatum*), and Bald Eagle (*Haliaeetus leucocephalus*). Development activities such as agriculture (e.g., wetland drainage), urban expansion, forestry, and mining have eliminated or alienated important habitat for these species throughout their ranges (Brownell and Oldham 1985, Holt and Leasure 1993, Cadman 1994, Rowell and Stepinsky 1997, Buehler 2000, Clayton 2000). Linear developments may negatively impact raptors through the loss and fragmentation of habitat, collisions with overhead wires and vehicles, and direct human disturbance (Postovit and Postovit 1987, Williams and Colson 1987, Watson 1993), but for most species, the effects of oil and gas exploration and development are little known and poorly understood.

Game Birds

The Ruffed Grouse (*Bonasa umbellus*) was the only key species selected for this group. This species tends to avoid homogenous habitats and areas inhabited by humans (Campbell et al. 1990b). There appears to be little information available on the effects of oil and gas exploration and development on this species, although there may be health risks associated with ingestion of, and dermal contact, with contaminated soils. Similar species are known to be vulnerable to disturbance. For example, human presence may displace Sharp-tailed Grouse (*Tympanuchus phasianellus*) from lek sites, although they are also known to habituate to various activities (e.g., road construction) (Baydack and Hein 1987, Connelly et al. 1998).

Passerines

Eight key passerine species were identified: Philadelphia Vireo (*Vireo philadelphicus*), Cape May Warbler (*Dendroica tigrina*), Black-throated Green Warbler (*Dendroica virens*), Bay-breasted Warbler (*Dendroica castanea*), Canada Warbler (*Wilsonia canadensis*), Connecticut Warbler (*Oporornis agilis*), LeConte's Sparrow (*Ammospiza leconteii*), and Nelson's Sharp-tailed Sparrow (*Ammodramus caudacutus nelsoni*). Unlike forestry-related activities, the impacts of oil and gas development on passerines have not been widely studied (William 1996, Cooper et al. 1997b, Norton 2001).

Obviously, habitat loss is a potential problem for any of these species. Habitat fragmentation is also a concern for many species. For example, the occurrence of the Connecticut Warbler in the aspen-parkland of Saskatchewan was positively related to aspen grove size and negatively related to grove isolation (Johns 1993, Bayne and Hobson 2000). Forest fragmentation (and resultant increase in edge habitat) can result in an increase in predation and nest parasitism (Bull and Jackson 1995, Moskoff and Robinson 1996, Cooper et al. 1997a). There was, however, apparently no effect of increasing seismic line development in Alberta's boreal forest on the Bay-breasted Warbler, despite the increase in habitat fragmentation (Cooper et al. 1997b, Norton 2001b). Air pollution from sour gas plants can affect the growth of deciduous trees by increasing disease frequency, and thus, indirectly reduce nesting habitat suitability for some passerines (Cooper et al. 1997b). There are also apparent mortality risks for Bay-breasted Warbler populations that are in the immediate vicinity of oil and gas plants that are producing SO_2 emissions (Cooper et al. 1997b).

Shorebirds

Two shorebirds were identified as key species: Upland Sandpiper (*Bartamia longicauda*) and Sandhill Crane (*Grus canadensis*). The major concern for shorebirds is the loss or alteration of wetland habitats that are critical to breeding and migration. The effects of oil and gas exploration and development on shorebirds are essentially unknown. Some shorebirds (e.g., Lesser Yellowlegs (*Tringa flavipes*)) have been observed to nest on roadsides, seismic lines, and agricultural fields (Campbell *et al.* 1990b).

Waterfowl

Four key waterfowl species were identified: Trumpeter Swan (*Cygnus buccinator*), Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), and Surf Scoter (*Melanitta perspicillata*). Considerable research has been conducted on the effects of development on geese and swans in northern Canada and Alaska. For example, Canada Geese were found to exhibit varying flight and alert responses to aircraft overflights according to aircraft type, altitude, and lateral distance (Ward *et al.* 1999). Construction of features such as gravel roads, pads, and quarries can result in loss of Tundra Swan (*Cygnus columbianus*) nesting habitat. Human activity (e.g., traffic) can lead to avoidance of areas within 100-200 m of roads, and may cause nest abandonment and increased predation risk (Ritchie and King 2000). Similar information for the Trumpeter Swan is not available, although human disturbances (e.g., boating, bird watching, floatplane use) can cause nest failure and loss of young (Mitchell 1994). There also appears to be no information on the effects of oil and gas exploration and development on Mallards and Surf Scoters, although habitat loss and alteration are a concern, particularly on wintering grounds and more southerly breeding areas (Savard et al. 1998, Government of Northwest Territories 2000).

3.7.3 Valued Components

A subset of the key species described above were selected as VECs for hot spot mapping. The primary criterion for selection was that an appropriate scale (regional) and format (digital map) of habitat value information was available. This criterion was met by 16 of the key species (Table 3-5). The habitat value database used was the BEI-based Wildlife Habitat Capability ratings product from MSRM.

A VEC representative of each of the regionally important wildlife groups (large carnivores, ungulates, furbearers, and birds) was also required. Within the wildlife groups, VEC selection was based on the regional profile of the species, the state of knowledge regarding oil and gas development and exploration impacts (species with a better knowledge base were given priority, whenever possible), and the severity of known impacts.

The VECs selected for hot spot mapping were grizzly bear, moose, marten, warblers, and caribou. Habitat capability mapping for each of these is provided in Figures 3-20 to 3-24 respectively. Habitat value information for the caribou was derived using BEU types and structural stage values (RIC 1998) that characterize their winter habitat.

Table 3-5. Selection of Wildlife VECs

Key Species	Availability of Information	Effects	Mapping	VEC
Woodland Caribou	Yes	Known – avoidance, increased mortality	Yes	Yes
Wood Bison	Very limited	Unknown		
Plains Bison	None	Unknown		
Moose	Yes	Known – avoidance, increased mortality	Yes	Yes
Stone Sheep	Very limited	Unknown – likely sensitive to disturbance	Yes	
Mountain Goat	Some indirectly	Probable – sensitive to disturbance	Yes	
Rocky Mountain Elk	Some	Known - avoidance	Yes	
White-tailed Deer	Very limited	Probable - avoidance, increased mortality	Yes	
Rocky Mountain Mule Deer	Yes	Known - some habituation	Yes	
Grizzly Bear	Yes	Known - avoidance, increased mortality	Yes	Yes
Black Bear	Some	Known - avoidance, increased mortality, some habituation		

Key Species	Availability of Information	Effects	Mapping	VEC
Wolf	Yes	Known – avoidance, predation facilitated		
Wolverine	Very limited	Probable – sensitive to disturbance		
Lynx	Yes	Known – some avoidance		
Fisher	Limited	Known – some avoidance	Yes	
Marten	Limited	Known – some avoidance	Yes	Yes
Aquatic Furbearers (beaver, muskrat)	Very limited	Unknown – likely minimal	Yes (beaver)	
Red Squirrel	Limited	Known – generally minimal		
Snowshoe Hare	Some	Known – increased mortality possible, generally minimal		
Northern Long-eared Myotis	None	Unknown – sensitive to disturbance		
Short-eared Owl	Limited	Probable – sensitive to disturbance		
Peregrine Falcon (*anatum* subspecies)	Limited	Probable – sensitive to disturbance		
Bald Eagle	Limited	Probable – sensitive to disturbance		
Ruffed Grouse	Very limited	Probable – increased mortality		
LeConte's Sparrow	Very limited	Unknown		
Nelson's Sharp-tailed Sparrow	Very limited	Unknown		
Bay-breasted Warbler	Very limited	Unknown	Yes	Yes[2]
Cape May Warbler	Very limited	Unknown	Yes	
Black-throated Green Warbler	Very limited	Unknown	Yes	
Canada Warbler	Very limited	Unknown	Yes	
Connecticut Warbler	Very limited	Unknown	Yes	
Philadelphia Vireo	Very limited	Unknown	Yes	
Sandhill Crane	Very limited	Unknown		
Upland Sandpiper	Very limited	Unknown		
Trumpeter Swan	Limited	Probable – sensitive to disturbance		
Canada Goose	Limited	Probable – sensitive to disturbance, some habituation		
Mallard	Very limited	Unknown		
Surf Scoter	Very limited	Unknown		

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[2] Generalized warbler habitat capability data were used rather than species-specific habitat capability data

3.7.4 Hot Spots

3.7.4.1 Grizzly Bear

The greatest grizzly bear hot spot concentration is in the southwest section of the Taiga Plains, east of Highway 97 and north of Beatton River (Figure 3-25). This area also corresponds to hot spot concentrations identified for marten and moose. There are some localized grizzly bear hot spots within the MKMA in the upper Muskwa River watershed and along the Kechika River between Turnagain River and Denetiah Creek. The majority of the Boreal Plains around and north of Fort St. John, much of the MKMA (in particular along the Rocky Mountain Foothills) and parts of the Liard Plateau are of some concern regarding cumulative effects impacts on grizzly bears. The remainder of the Interior Plateau is essentially of negligible concern, as expected, given that grizzly bear habitat capability in this region is predominantly rated nil.

3.7.4.2 Moose and Marten

The greatest hot spot concentration for both moose and marten is in the southern third of the Interior Plateau (Figures 3-26 and 3-27, respectively). There is also a smaller hot spot concentration for these species around Fort Nelson. Areas of some concern regarding cumulative effects impacts on marten are common and present throughout the study area. Areas of some concern for moose are concentrated along the Rocky Mountain Foothills and in the Kechika watershed, with some areas scattered at moderate density throughout the Interior Plateau.

3.7.4.3 Warbler

There are no significant concentrations of warbler hot spots in the study area (Figure 3-28). This reflects the apparent lack of high capability warbler habitat in the region, and a limited understanding of this group's habitat requirements in the northeast. There are areas of some concern regarding cumulative effects outside of the MKMA, particularly in the Boreal Plains and scattered throughout the Taiga Plains.

3.7.4.4 Caribou

The greatest caribou winter habitat hot spot concentration is in the southern third of the Interior Plateau (Figure 3-29). This area corresponds to hot spot concentrations identified for marten and moose. There are also smaller hot spot concentrations around Fort Nelson, along the Liard River and onto the Liard Plateau, and south of Kotcho Lake. There are almost no hot spot areas in the MKMA, although there are areas of some concern along the Rocky Mountain Trench and parts of the Rocky Mountain Foothills.

3.8 Summary

Table 3-6 provides a summary of key hot spot map attributes for each environmental component, including issues, VECs, what was mapped, and general observations about the nature of the hot spots.

Table 3-6. Hot Spot Map Summary

Discipline	Issues	VECs	Mapped Theme[1]	Categories	Observation[2]
Air Quality	Possible exceedance of air quality thresholds	Air quality in local and regional airsheds	Well SO_2 emission-density (Figure 3-11)	0-15,000 m^3 SO_2/km^2	Concentrated emissions clusters occur throughout Interior Plateau; negligible emissions occur in MKMA
Soils and Terrain	Reduction in soil quality	Soil types sensitive to acid input	Soil acid sensitivity (Figure 3-13)	Hot spot	One large hot spot cluster located northeast of Headwaters Ranch; a few small hot spot clusters occur in the Interior Plateau and MKMA
	Soil loss	Soil quantity	Erosion risk (Figure 3-14)	Negligible concern Some concern Moderately disturbed Highly disturbed	Majority of study area of negligible concern; numerous very small moderately and highly disturbed areas clustered around Fort St. John and scattered throughout MKMA
Aquatic Ecosystems	Reduction of water quality Degradation of fish habitat	Bull trout Arctic grayling Water quality	Important habitat (drainages) for fish VECs (Figure 3-16)	Areal coverage for each species	*Bull trout*: two hot spot areas, one associated with upper Prophet River watershed and the other with Halfway River watershed *Arctic grayling*: large hot spot patch extending through the eastern slopes and across the mid-region of Interior Plateau[3]
Vegetation	Removal or damage to vegetation	Old growth forests Wetlands Rare plants	Sensitive features (Figure 3-18)	Negligible concern Some concern Moderately disturbed Highly disturbed	Majority of hot spots occur in Interior Plateau; clusters of highly disturbed areas throughout southern portion of study area; numerous patches of moderately disturbed areas throughout the remainder of the Interior Plateau[4]

Discipline	Issues	VECs	Mapped Theme[1]	Categories	Observation[2]
Wildlife	Loss or reduction in capability and effectiveness of habitat Habitat fragmentation Direct mortality Disruption of movements	Grizzly Bear Moose Marten Warbler	Habitat capability (Figures 3-25, 3-26, 3-27, 3-28)	Negligible concern Some concern Moderately disturbed Highly disturbed	*Grizzly bear*: highly disturbed patches northeast of Headwaters Ranch; areas of some concern occur throughout the southern Interior Plateau and along the MKMA foothills and Rocky Mountain Trench *Moose*: large patch of highly disturbed area located in the southern Interior Plateau; some areas of moderate concern and of some concern occur in the eastern portion of MKMA *Marten*: highly disturbed clusters occur in the southern Interior Plateau; extensive patches and clusters of some concern occur in remainder of the study area *Warbler*: majority of hot spots occur in Interior Plateau, very small patches of highly disturbed and moderately disturbed areas, a few patches of some concern
		Caribou	Winter habitat (Figure 3-29)		Large clusters of highly disturbed, moderately disturbed areas in southern Interior Plateau; clusters of some concern throughout the study area

1. The theme is what the map was based on. Not included here is, common to all hot spot maps, inclusion of the correlation with areas of human use.
2. A patch is a contiguous geographic area of coverage for a given category that is isolated from other patches. A cluster is a pattern of many patches.
3. Areas of water quality concern are directly correlated with fish habitat categories.
4. Hot spot theme does not distinguish between each of the three VECs. It reflects areas of concern for the three VECs combined.

CHAPTER 4: REGIONAL FRAMEWORK

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY

4 Regional Framework

4.1 Solving the Cumulative Effects Problem

4.1.1 What is the Problem?

The problem is that things we value in the natural environment may be harmed or lost if human disturbances happen too often and too quickly for us to take appropriate action. The response of the environment is called a cumulative effect, an effect that considers all manner of influences by humans. Over time, an observer of changes to a landscape – a landscape where people are building, working, living, and traveling – will notice that the more we do, the less we see of the landscape that we are building, working, living, and traveling on. An observer would also note that many of these human actions just happen, and while some happen as a result of government decisions, in most cases, actions are driven by commerce or personal wish.

Although there are administrative processes in place to govern many such actions, the decisions to do so often are made in consideration of each individual action at a time. Eventually, this independence of decision-making becomes apparent when an environmental effect on something we value becomes unacceptable, by whatever definition — this is the problem of addressing cumulative effects. That is, decisions made in isolation produce environmental results that appear collectively.

From the point of view of regulatory decision-makers, particularly those responsible for processing numerous applications (such as OGC staff, including resource officers and managers), addressing cumulative effects in any practical and meaningful fashion immediately becomes a problem of administrative resources and logistics. From the point of view of land and resource decision-makers, such as government planners, and those with overarching mandates (such as regional boards and committees), addressing cumulative effects becomes a problem of prioritization and having a clear and definable objective. For these decision-makers, the problem is not having the information and tools they need to help them make better decisions.

Cumulative effects are often 'made real' for decision-makers or advisory bodies when they are faced with various situations suggesting a cumulative effects problem; for example:

- A proponent wishes to construct another well in a certain area (e.g., a valley, a new natural gas pool) that is currently occupied by a number of other resource users. The question arises: will this additional application compromise something of environmental importance?
- A proponent wishes to construct a resource access road in a topographically constrained area, such as a valley, that is currently inaccessible except by an ATV trail. The question arises: what are the future implications of more use once the road is built?[1]

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[1] Such possible future actions are typically referred to as 'induced' projects or activities, which in its general meaning refers to any human action that may occur as a consequence of an earlier action.

- An area of well-defined boundaries is already experiencing 'boom' conditions and applications for project approvals are coming in faster than due process allows time to investigate some matters of environmental concern (unless substantial delay occurs in the reviews). The question arises: what is the most effective way in such situations to not compromise on environmental responsibilities?
- An area of generally understood boundaries, currently experiencing minor human use, is expected to substantially 'pick up' in the future in regards to resource extraction (e.g., coal bed methane, natural gas or timber harvesting). The question arises: what can be done now to prepare for this eventuality?

4.1.2 What is the Solution?

It would seem at first that the only solution to the problem of cumulative effects, or at least a principle contributor to a solution, is to fully coordinate the pace and type of all human uses so as to ensure the environmental features we value are not harmed or lost. This approach, reflecting the desire to replace independent decision-making on each action with a coordinated and informed process for all projects, is called a framework - in this case, a Cumulative Effects Assessment and Management Framework (CEAMF), a term that says we both assess what is important to us and manage what we are assessing. The concept of such frameworks has been both studied (AXYS 2000, Macleod Institute 2000, Pollution Probe 2001) and already implemented in other regions (Appendix B).

The term "framework" implies the collection of many pieces, tied together. It also implies an approach that moves beyond individual project decision-making to a process that relies on more broad approaches, of which such decision-making is only one part. It is also an attempt to overcome the weaknesses of individual project decision-making; namely, the isolation of decisions and the failure to incorporate measures and means of determining if now, soon, or some time much later the environmental feature we wish to manage remains as we want it. But to do this, we must already know what we want and, by default, know when something that we value is no longer as we want it. The point when the condition of the environmental feature becomes unacceptable is called a threshold. To determine thresholds, we must then have clear land and resource use objectives in mind, whether broadly for everything over large areas, or specifically within a certain area for a specific environmental feature. Results of planning processes already in place, such as LRMPs and SRMPs, provide some qualitative measure of these objectives.

The observer of the changing landscape would likely say that to solve the cumulative effects problem, one needs thresholds and, at minimum, information to place individual human actions (projects) into some form of a regional context. This context then allows a comparison of the contribution of effects from each action to its surroundings, and then allows a decision-maker to determine if enough has happened, and if future human activity must stop or be sharply curtailed; in other words, to find out "when enough is enough".

It is true that, ultimately, the review of individual project applications will not solve the cumulative effects problem. It may help in slowing down the pace of change, such as through use of mitigation, or more broadly, through the management of project-specific effects thus minimizing the possibility that these effects will act cumulatively with the effects of other projects. However, unless individual project reviews are done well, over time and depending on circumstances, the recovery of an environmental feature to a desired state will inevitably become more difficult. Yet while a regional perspective is desirable, the practical checking and tracking of individual projects across a landscape is, for better or worse, what we must deal with, as that often is all we have. In some fortunate cases, efforts have been made to look at large regions and declare what is important, what is allowed and not allowed, and to provide some measure by which to plan human use before it actually happens. In most cases, we are not really there yet.

4.1.2.1 The Sustainable Resource Management Strategy

In reality, the problem of cumulative effects is not as simple as described above, and the solution is not as obvious to even the most astute and educated observer. We have, on one hand, what can be done with each project as it arises, and on the other hand, what can be done for all projects before any arise. The first, while readily implementable, is not especially effective in addressing the problem; the latter, while more focused on the problem, requires substantially more effort and time.

Ideally, two integrated approaches, working together and based on the elements introduced in the two linked volumes of this study, should form the basis of an implementable framework (Figure 4-1). It is this dual-tracked approach that is discussed in more detail in Section 4.7. The approach, specific to the needs of the northeast BC region, is referred to as the Sustainable Resource Management Strategy (SRMS) in recognition that the assessment and management of cumulative effects is only an interim step along the way to what is ultimately what decision-makers in the region are tasked to accomplish; namely, the sustainable management of land, water, and air resources.[2]

The term Sustainable Resource Management Strategy (SRMS) is adopted from MSRM's recently implemented Sustainable Resource Management Plan (SRMP), the latter an "umbrella approach to foster economic development and environmental sustainability through strategic resource planning". The SRMS as outlined in this volume describes an approach that links application review by the OGC (and possibly other regulators) and regional planning to specifically assess and manage cumulative effects throughout northeast BC, including the MKMA, with a focus that reflects the OGC's mandate and process.

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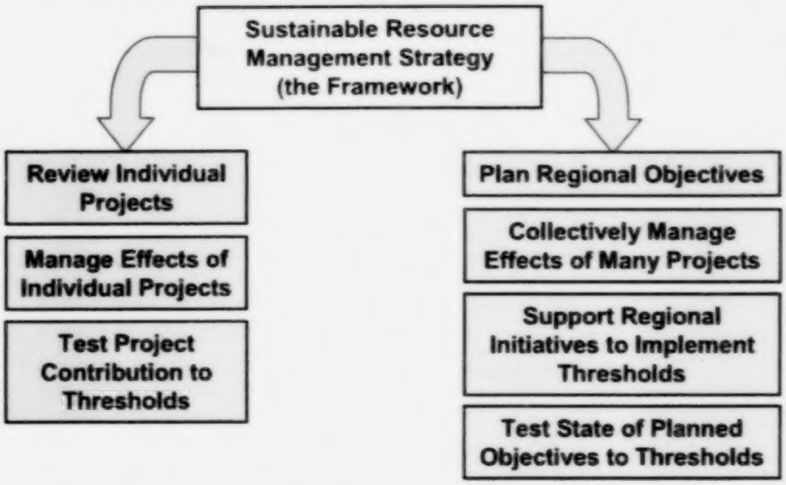
[2] This CEAMF report does not attempt to address the definition of sustainability and its meaningful and practical interpretation. The intent of the sustainability concept is generally well-understood and is indeed relevant to the proposed SRMS. However, a more refined definition of sustainability as it applies to northeast BC and to matters of cumulative effects would need to be adopted from existing and ongoing efforts by the BC Government, and possibly elsewhere.

Figure 4-1. Framework Overview


Sustainable Resource Management Strategy (the Framework)
Review Individual Projects
Manage Effects of Individual Projects
Test Project Contribution to Thresholds
Plan Regional Objectives
Collectively Manage Effects of Many Projects
Support Regional Initiatives to Implement Thresholds
Test State of Planned Objectives to Thresholds

Further evolution of a CEAMF in northeast BC will reveal the extent of incorporation of elements of both the strategy and plans, the former implying the incorporation of long-term approaches to manage the cumulative effects of land and resource use over a large geographic region subject to many land use pressures, and the latter implying similar focused efforts over specific (and likely smaller) geographic areas within the region.

The SRMS is a practical approach that can contribute to solving the complex cumulative effects problem. This approach does the best that can be done in the absence of thresholds, does whatever is possible to identify thresholds, and is ready to use thresholds once available to practically implement.

The SRMS is proposed here as a Cumulative Effects Assessment and Management Framework (CEAMF) that is customized for the northeast BC. As such, the term SRMS will be used in the remainder of this section in references to the framework concept instead of the generic CEAMF.

In summary, the SRMS is based on the following key principles:

1. **Dual-track Approach**: Cumulative effects can be tackled both by addressing individual projects and by undertaking regional initiatives on different time scales (i.e., those that are not directly tied by regulatory mechanisms to any one specific sector or project). The latter approach is better; however, most administrative and regulatory processes are currently built on, and fully resourced for, the review of individual applications.

2. **Effects Management Implementation**: The management of project effects, whether implemented for individual projects at a time or jointly for various projects, provides immediate to near-term opportunities to eliminate or substantially reduce environmental effects and the pace at which those effects occur.

3. **Threshold Implementation**: Candidate thresholds are available (as provided in Volume 2); however, their practical implementation will take time given the need to develop capacity to support them and to obtain agreement by stakeholders. Once approved within a practical implementation process that is not onerous, use of a wide suite of context-specific thresholds (i.e., correlated to specific areas and environmental features of concern), whether as part of project-specific review or regional land use planning, offer an effective tool to address cumulative effects.

4. **Administrative Co-ordination**: Co-ordination of resource use decisions amongst government, and the availability of information to support decision-making, is required as meaningful solutions to the cumulative effects problems are enhanced. As such, a central Steering Committee or equivalent is required to facilitate coordination of the SRMS.

5. **Flexibility of Phased Options**: Instead of an over-arching framework that supplants existing institutional responsibilities, the proposed SRMS is based on many tools or options that will each contribute in their own way, or will collectively work together over time. Each option provides an opportunity, at earlier or later points in time depending on the resources available, to support them and their acceptance at whatever government, industry, and public level of participation is appropriate.

6. **Shared Responsibility**: Solution of the cumulative effects problem is, ultimately, a shared responsibility of regional stakeholders. In this way, the dual mandate of protecting the natural environment and accessing and extracting natural resources can benefit by the recognition of compromise and the support of new initiatives. Such initiatives, ultimately, require some measure of restraint, although not necessarily cessation, of current ad-hoc development.

7. **Implementation of Goals**: The framework, through the use of thresholds and various levels of land and resource use plans, provides an opportunity to imbed goals (e.g., for resource utilization and resource harvesting) that can assist in addressing cumulative effects.

8. **Adaptive Management**: Through the implementation of monitoring, information can be updated upon which to continuously improve subsequent decision-making.

4.2 Role of Individual Project Application Assessments

4.2.1 Environmental Impact Assessment

4.2.1.1 What is an EIA and How to Do One

An Environmental Impact Assessment (EIA) is an examination of the effects of a project subject to regulatory review. To do an EIA implies a complete and systematic assessment of all likely cause-effect relationships attributable to the project. An EIA typically also implies that a greater level of such scrutiny is applied than for screening level reviews, although screening level reviews borrow the basic concepts of the typically more comprehensive EIAs.

In any EIA, the primary assessor is the proponent. The secondary assessor (typically, the regulatory reviewer) reviews the assessment and decides if it is satisfactory for its purposes.

If a detailed project assessment (i.e., Environmental Impact Assessment) is required, then the following five steps, common to a full EIA process, are followed:[3]

1. **Scoping**: the early identification of key aspects of the assessment, including issues of concern, valued ecosystem components, spatial boundaries, temporal boundaries, project impacts that lead to various effects, and other projects contributing cumulatively to the same effects.

2. **Analysis**: the prediction of effects of the project alone (project-specific effects) and in combination with effects from other human disturbances (cumulative effects), done through the use of appropriate analytical tools (e.g., spatial and numerical modeling).

3. **Mitigation**: the identification of approaches to manage any negative effects by eliminating or reducing the effect (e.g., air emissions controls, minimization of cleared areas).

4. **Significance**: the evaluation of how important the residual effect (i.e., after mitigation) is, based on appropriate criteria that establish the context in which that effect may be compared (e.g., regulatory guideline, land use policy, scientific empirical evidence, level of social acceptable change, thresholds).

5. **Follow-up**: monitoring of the project to verify implementation and effectiveness of mitigation, and to verify accuracy of prediction of effects.

For oil and gas projects, guidance on options for these steps is provided in Appendix F: Oil and Gas Project Assessment Matrices. Specifically, the matrices provide information for each environmental component reviewed (Section 3) in the Regional Assessment (air and noise, soils and terrain, aquatic ecosystems, vegetation, wildlife, and land use). They include generic information applicable to all types of oil and gas projects, as well as specific information applicable to selected types of oil and gas projects: seismic, exploration drilling, production, and pipelines. These matrices may be modified by users depending on the specific context of project design and environmental setting.

4.2.1.2 What Projects are Subject to EIAs?

The majority of projects in BC (as for most jurisdictions) are however not subject to formal environmental impact assessment (EIA) under the jurisdiction's EIA regulatory review process, and so, there is little opportunity to formally address cumulative effects that way. The *Reviewable Projects Regulation* of the BC *Environmental Assessment Act*, and its federal equivalent under CEAA (the *Law List Regulations*), make clear that only a few energy projects may be assessed in full under the provisions of such acts.

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[3] It is beyond the scope of this report to describe these steps in detail. Detailed guidance on their completion is available from the *Cumulative Effects Assessment Practitioners Guide* (Hegmann *et al.* 1999), which can be accessed from CEAA's website at http://www.ceaa-acee.gc.ca/0011/0001/0004/index_e.htm, or purchased from that agency.

In BC (as in Alberta), this means that the majority of the smaller projects in the oil and gas industry (including geophysical operations [seismic], exploratory and production wells, access roads to wells, most plants, and most pipelines) are not subject to such reviews; or if subject to some provision requiring the consideration of environmental effects (e.g., permitting and licensing of such activities), typically include a limited response to cumulative effects in comparison to that undertaken for a full EIA.

4.2.2 The OGC's Current Review Process

The OGC, as is typical with all provincial (and federal) ministries/agencies, first screens each application received and subjects it to checks, as appropriate under its administrative or regulatory mandate. The OGC process, as is the case with most such reviewing bodies, currently has limited explicit reference to cumulative effects in such reviews or the availability of meaningful resources in which to test each project application in the context of its particular contributions to cumulative effects. Notwithstanding this, the OGC is currently exercising opportunities to address cumulative effects through several of its own initiatives (e.g., the General Development Permit, consultation and referrals) or through its involvement with initiatives led by other jurisdictions (e.g., land use planning).

As such, the checks and balances of due process make use, when possible, of information that may assist this effort; however, the efficient and timely processing of applications, the lack of required information, and ultimately, the lack of thresholds mean that the pursuit of cumulative effects-related problems (and solutions) likely do not yet occur, except in the most exceptional of circumstances.

The current OGC review process is shown in Figure 4-2. This process essentially consists of three principle parts: screener, referrals, and decision (Figure 4-3). At the preliminary level, each proposed project is classified as simple (e.g., on private land, non-sour wells, simple water crossings), normal (e.g., on Crown land), or complex (e.g., sour wells, in Special Management Areas, environmentally complex). Each classification implies a certain level of review commensurate to the project's issues.

4.2.3 A Modified OGC Review Process

4.2.3.1 Basis of Approach

There is an opportunity within the current OGC review process to usefully incorporate consideration of cumulative effects for individual project applications that is not onerous, and would not threaten the timely and efficient review process, assuming that certain information sources are available. Such an approach is based on the view that OGC staff do not always have extensive time to spend on individual applications; therefore, a series of quick tests are required that are designed well enough to ensure that projects of concern are captured.

This modified screening process is referred to here as the OGC Application Cumulative Effects Screener (ACES). It's position in the current OGC process (i.e., where it fits in) is shown in Figure 4-3, with ACES shown in summary. Figure 4-4 shows ACES in detail.

Under the proposed modified approach, an application would enter and exit the OGC review process in the same way it does now. However, imbedded in the screening stage of the review process would be a formal screening for cumulative effects. The level of detail of the cumulative effects screen (see below for details) would depend on whether the application was 'routine' or requires an expanded review, of which an 'advanced' cumulative effects screening would be one component (clear criteria are defined for moving from a routine to an expanded level of review).

To make this approach as practical and readily implementable as possible, a modified screening level process that explicitly addresses cumulative effects is used that is based on a series of five steps: conformance check, thresholds check, effects check, effects management selection and monitoring selection.

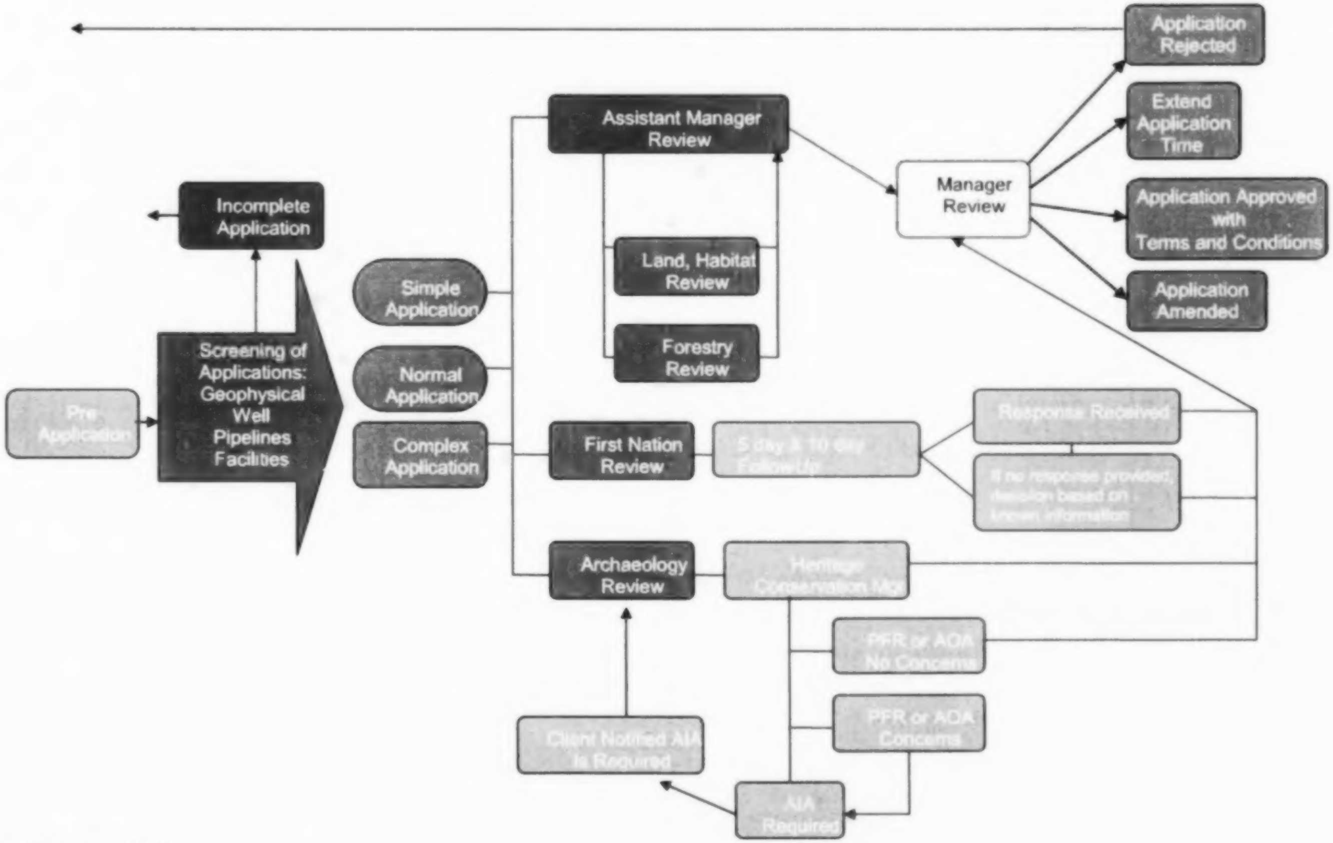
This addition to the current OGC screening step, described in more detail below and in Appendix G, makes use of various elements of the framework described throughout this volume. OGC staff would assimilate various sources of information, by then readily available, to assist in incorporating consideration of cumulative effects into the decision-making process. This process is also generic enough to be readily adapted by any other application reviewing body.

A pilot implementation program, including training, is also proposed (Appendix G) that the OGC may use to test the proposed ACES process in actual application review conditions, but in a parallel process that does not affect the fate of the application. In this way OGC staff familiarize themselves with the process and suggest modifications to customize the process further, if necessary, to best meet the needs of the OGC prior to full implementation.

In summary, attributes of ACES include:

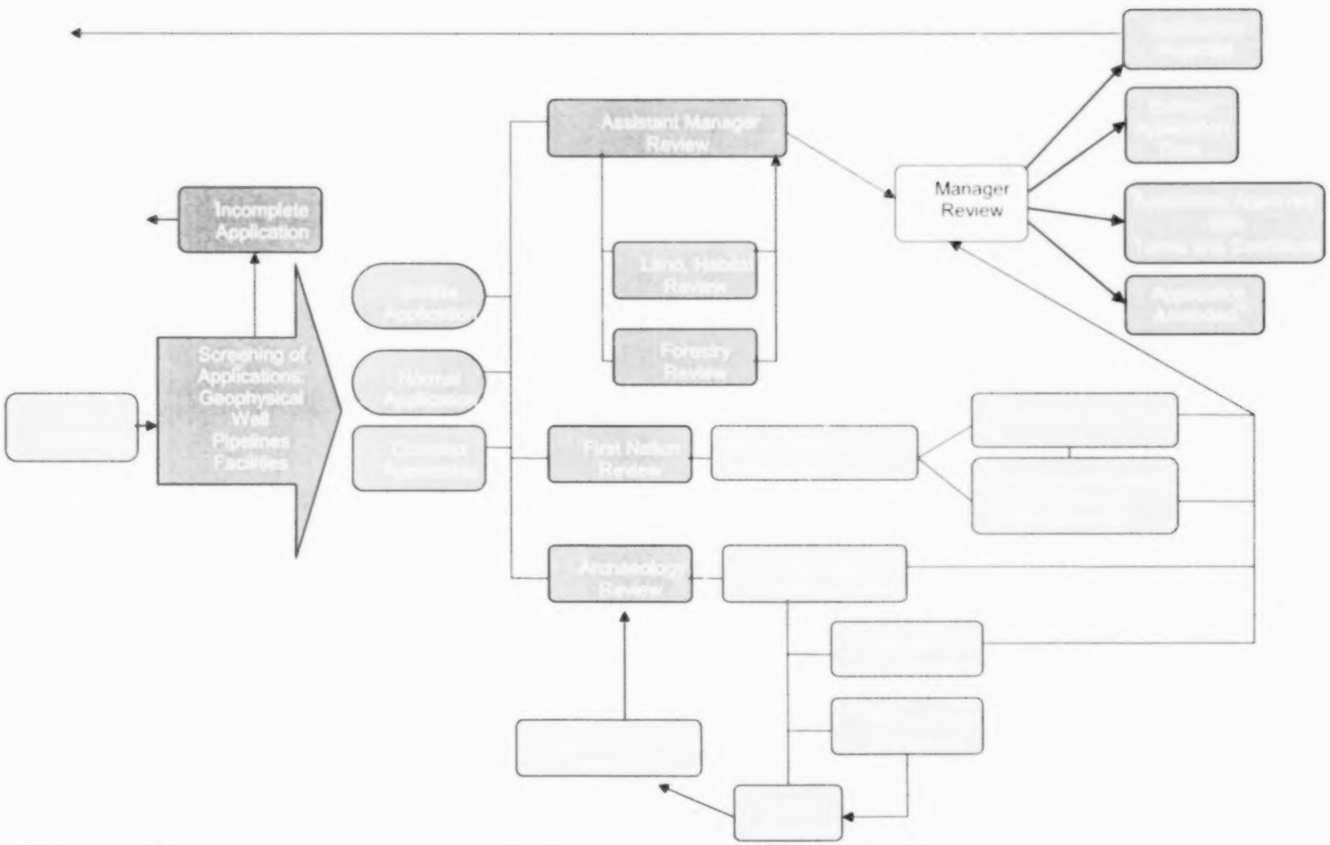
- clear linkages to the existing OGC application review process;
- a series of steps or 'checks' to determine and address the cumulative effects of both routine and complex applications, providing a proportional review response based on the likelihood of effects of concern;
- identification and use of various information sources (including a regional data base), most of which are currently available and some of which would become available upon implementation of the proposed SRMS;
- implementation of thresholds (where and when available);
- continued use of referrals (e.g., First Nations, land management agencies) as a means of obtaining broader input;
- clear guidance to proponents on information requirements; and
- clear guidance to reviewers to assist them in determining the fate of an application.

Figure 4-2. Existing OGC Application Review Process



(from OGC 2002)

Figure 4-2. Existing OGC Application Review Process



(from OGC 2002)

Figure 4-3. Relationship of ACES to Existing OGC Review Process

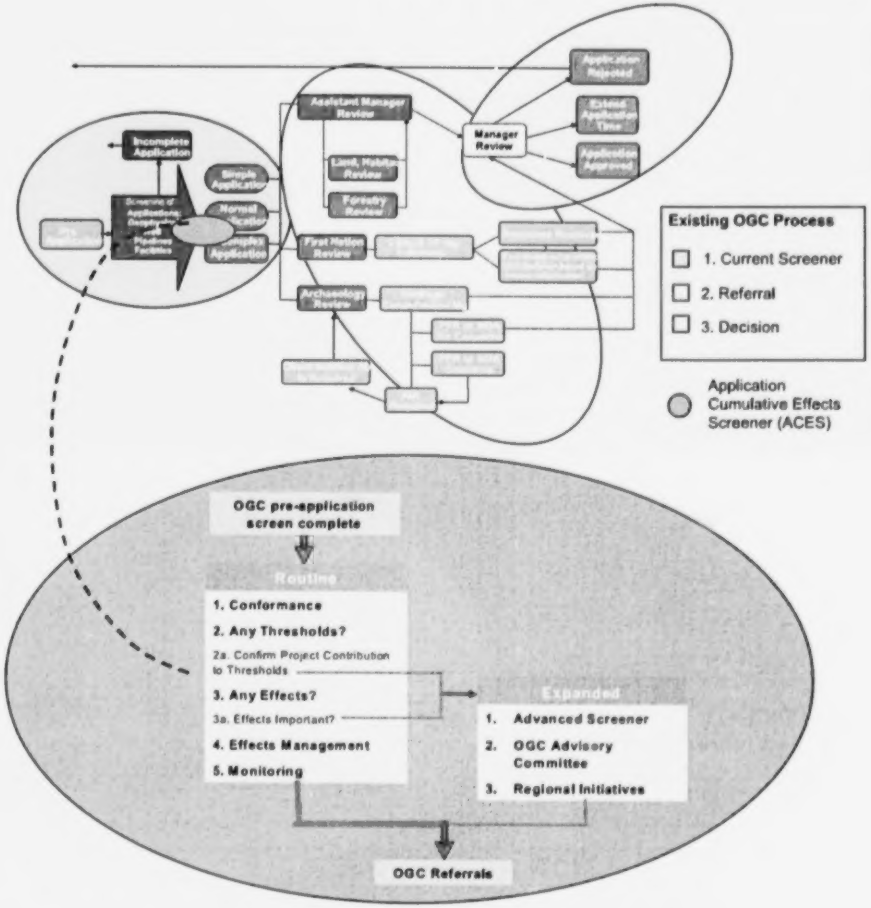


Figure 4-4. Application Cumulative Effects Screener Details

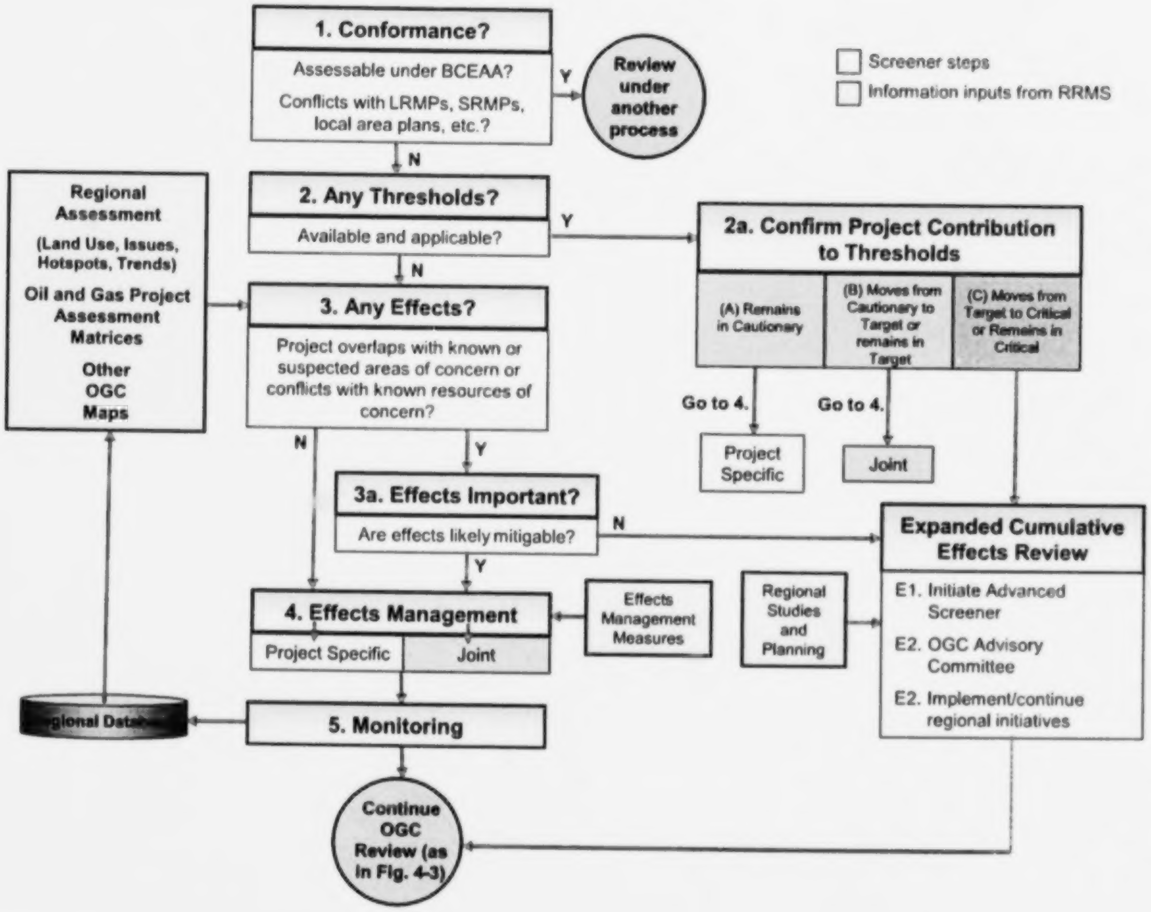
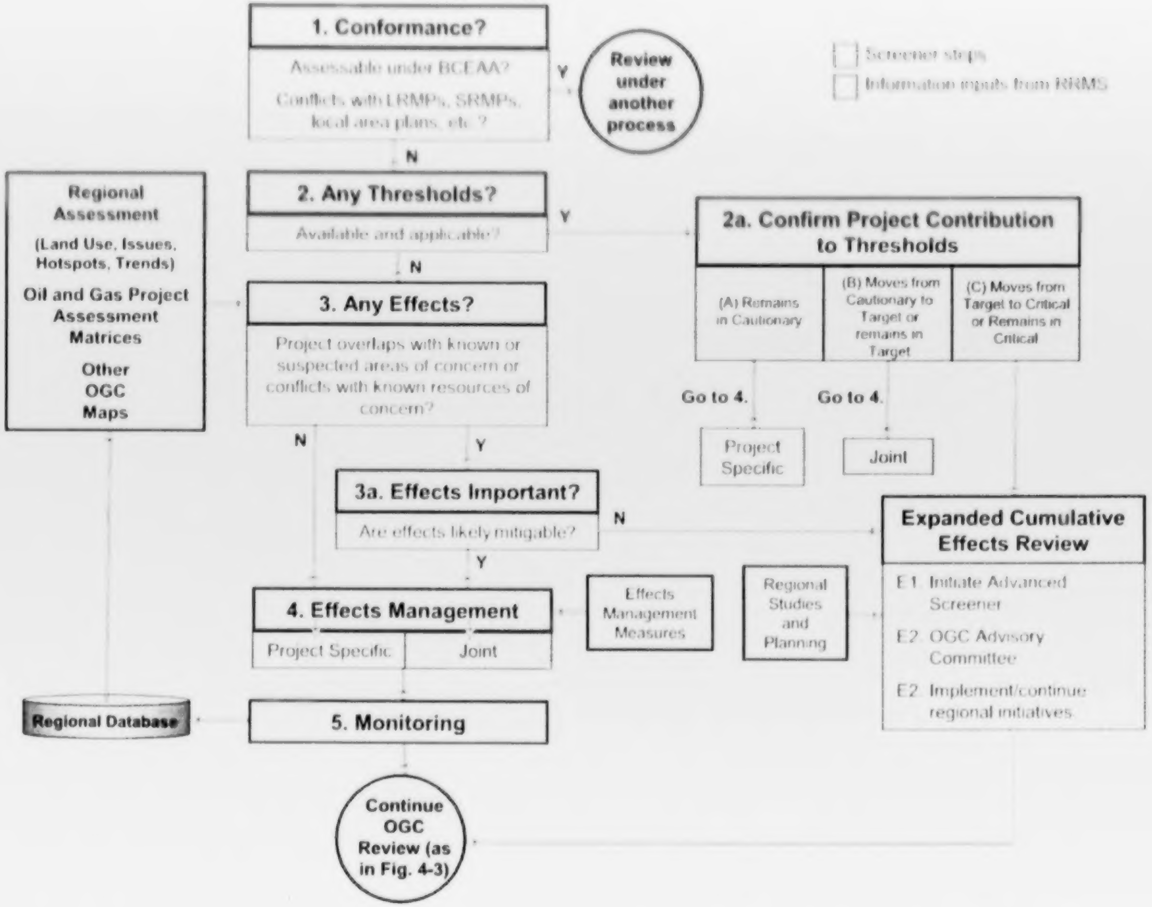

1. Conformance?
Assessable under BCEAA?
Conflicts with LRMPs, SRMPs, local area plans, etc.?
Y
Review under another process
N
Screener steps
Information inputs from RRMS
Regional Assessment
(Land Use, Issues, Hotspots, Trends)
Oil and Gas Project Assessment Matrices
Other OGC Maps
2. Any Thresholds?
Available and applicable?
Y
2a. Confirm Project Contribution to Thresholds
(A) Remains in Cautionary
(B) Moves from Cautionary to Target or remains in Target
(C) Moves from Target to Critical or Remains in Critical
N
3. Any Effects?
Project overlaps with known or suspected areas of concern or conflicts with known resources of concern?
Go to 4.
Go to 4.
Project Specific
Joint
N
Y
3a. Effects Important?
Are effects likely mitigable?
N
Expanded Cumulative Effects Review
E1. Initiate Advanced Screener
E2. OGC Advisory Committee
E2. Implement/continue regional initiatives
Y
4. Effects Management
Project Specific
Joint
Effects Management Measures
Regional Studies and Planning
Regional Database
5. Monitoring
Continue OGC Review (as in Fig. 4-3)

Figure 4-4. Application Cumulative Effects Screener Details


1. Conformance?
Assessable under BCEAA?
Conflicts with LRMPs, SRMPs, local area plans, etc.?
Y
Review under another process
N
Screener steps
Information inputs from RRMS
Regional Assessment
(Land Use, Issues, Hotspots, Trends)
Oil and Gas Project Assessment Matrices
Other OGC Maps
2. Any Thresholds?
Available and applicable?
Y
2a. Confirm Project Contribution to Thresholds
(A) Remains in Cautionary
(B) Moves from Cautionary to Target or remains in Target
(C) Moves from Target to Critical or Remains in Critical
Go to 4.
Go to 4.
Project Specific
Joint
N
3. Any Effects?
Project overlaps with known or suspected areas of concern or conflicts with known resources of concern?
N
Y
3a. Effects Important?
Are effects likely mitigable?
N
Y
Expanded Cumulative Effects Review
E1. Initiate Advanced Screener
E2. OGC Advisory Committee
E2. Implement/continue regional initiatives
4. Effects Management
Project Specific
Joint
Effects Management Measures
Regional Studies and Planning
Regional Database
5. Monitoring
Continue OGC Review (as in Fig. 4-3)

4.2.3.2 Levels of Review

Routine Screening

The routine level of screening is the simpler of the two levels in terms of information and effort required. It is based on a few relatively simple questions and tests performed by the OGC application reviewer. The approach relies on the identification of effective effects management measures (EMMs) or the use of thresholds if available. This level would be applied to the vast majority of applications in any given year.

As shown in Figure 4-4, this approach includes two options based on whether thresholds are not available (steps 1, 2, 3, 4, and 5) or are available (steps 1, 2, 2a, 4, and 5). The only incremental information requirement for applicants is the calculation of their project's contribution to thresholds (if thresholds are being implemented for the region in which their project is located).

A checklist-based form is provided and explained (Appendix G) to guide OGC staff through a routine screening.

Expanded Review

The expanded level of review ensures that projects (of which few are anticipated) that may substantially contribute to a matter of concern, or for which unacceptable uncertainty exists, are 'captured' and assessed accordingly in proportion to those concerns.

The expanded level of screening involves a more detailed review of the application, placing the project under further scrutiny. Use of the term 'review' implies a higher level of assessment than a screening, but not a full EIA (unless further inquiry raises this possibility). It is based on a more expansive approach to addressing cumulative effects than the routine screen. The approach relies on more detailed information of the project's potential effects and on the involvement of more external advice. It also assumes that broader regional effects management initiatives are (or would be) in place. An expanded review is triggered by two criteria (in step 2a, based on thresholds; and, in step 3a, based on ability to mitigate effects) at the routine level. It is anticipated that an expanded review would be required for only a few applications in any given year.

The expanded review reflects an admission that, in some cases and for certain complex projects, effects cannot be readily mitigated away, and that eventually there will be a combination of circumstances that requires mechanisms to address a project beyond the reliance on EMMs or threshold checks. Also, the expanded review ensures that even facing such challenging circumstances, a project continues to receive an opportunity to be considered for approval, with the caveat of being subject to more rigorous review.

As shown in Figure 4-4, this approach includes three parts: i) advanced screener; ii) OGC Advisory Committee; and iii) regional initiatives. This level of review does include further information requirement from proponents.

A checklist based form is provided and explained (Appendix G) to guide the OGC staff through an expanded review.

4.2.3.3 What Additionally is Required?

OGC application reviewers must have additional time to complete a series of checks and selections. The introduction of a cumulative effects component to the application review process assumes that reviewers have adequate knowledge of project types and the regional context to accurately characterize the effects of a project and how such effects may interact with those of other existing or proposed projects. The approach also assumes that information to support a review of cumulative effects, mainly mapped information at an appropriate spatial scale, is readily accessible to reviewers.

If thresholds are available, then they are used; and, if not available, reliance on other means is required.

Where thresholds are available, a project's contribution to a regional threshold would provide the essential test of project acceptability. In such cases, applicants would provide the OGC with a calculation of their project's contribution to the threshold (as explained in more detail in Volume 2). However, it should be noted that even in the worst of situations, a project is never outright rejected until it at least has received the opportunity to be reviewed in more detail. If deemed acceptable, approaches to management of effects would then be determined.

Where thresholds are not available, the likelihood and level of concern (i.e., significance) of potential cumulative effects to which an individual project may contribute are estimated (e.g., in consideration of information in land use plans). This is based on the location of the project (therefore, relying on maps) relative to coarse scale indicators, for which suggestions are provided for specific sources of information. The principle mechanism for addressing cumulative effects is then through effects management, for which options are provided (many, which if implemented well, will prove effective in reducing the rate of adverse environmental change).

Considerable reliance is placed on effects management measures to mitigate potential project effects, reflecting a key attribute of the proposed strategy. Furthermore, additional mitigation is required in the form of joint initiatives in cases of specific possible concerns (thereby creating two levels of mitigation, project-specific and joint). Any project directed to a joint level of mitigation also is subject to any appropriate project-specific mitigation.

4.2.3.4 Information Requirements

The ACES makes two major assumptions: i) the OGC reviewing officer is familiar enough with the types of projects being reviewed to characterize typical environmental effects of such projects; and ii) that readily accessible and comprehensive information is available to assist the reviewer. Ultimately, useful information must be provided to the OGC decision maker (whether the resource officer assigned to a particular project or a manager) so that they, with the additional consideration of cumulative effects, can exercise their decision-making duty. Supplementing this information is any field knowledge gained by OGC staff, and any information subsequently gained through field inspections.

A considerable amount of information is currently available to assist OGC staff and other application reviewers in screening project applications. The proponent, as part of the application process, is required to submit detailed information about their project. Additionally, the OGC's Electronic Petroleum Application Submission (ePASS) system will allow proponents, when implemented, to submit an electronic file of their project footprint[4] (as well as other component of their land use application), which allows OGC staff to more easily map the location of the project in relation to other existing and proposed projects in the same area – an important step in assessing and managing cumulative effects.

Only a minimum of new information is required for routine applications; any information used is that which is readily available. The routine screening level relies on relatively accessible information (i.e., project design, location and typical mitigation) than are required in a potentially more complicated examination of project effects (which are addressed in the expanded review).

Applicants are not called upon for more information for the majority of applications (routine) except when thresholds are implemented as part of the review process; and, applicants are required to provide further information if their application proceeds to an expanded review.

Regional Information

Regional-scale information is available through a variety of sources, many of which have been summarised in this Volume. A comprehensive, accurate and up-to-date database of regional information is critical to the success of the SRMS. Currently, the Ministry of Sustainable Resource Management (MSRM) maintains spatial data for the region and makes these data available to other ministries, government organisations and the public.

The OGC's existing use of the GIS-Oracle Access Tool (GOAT), which includes map coverages, relies on the MSRM database and makes this information available to all OGC staff. As part of the regional assessment (Section 3), data themes contained with the MSRM database were used to generate a series of baseline and hot spot maps showing the geographic distributions of environmental features and values, as well as areas where critical values overlap with existing or proposed development activity. These maps are available for use by OGC staff, although these currently represent only a selected number of disciplines and values.

Information collected in support of an individual project assessment will contribute to the compilation of a regional database (already begun as part of this study), and thus, will build upon existing knowledge of the region's ecological and social components. This process is an important contribution to the SRMS as it increases our understanding of how the environment responds to past human actions, and will increase our understanding of the consequences of future development. This heightened understanding may also assist in the design of more effective mitigation tools and thresholds to limit and manage environmental effects.

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[4] Spatial entities that comprise the project footprint may include: seismic lines, well sites, pipeline rights-of-way, water crossings, well hold locations, ancillary or other facilities, Water Act application locations, and road centre lines.

Summary of Information Needs

In summary, the following information is required to complete a routine screening using the approach described above:

- The proponent's application, which includes a detailed description of the proposed project, its location(s), the project footprint, and all proposed mitigation and effects management measures;
- If thresholds are available for the area in question, the application should also include the proponent's calculation of their contribution to the applicable thresholds;
- If no thresholds exist, OGC staff should have sufficient information to compare the location of the proposed project to that of any other existing or reasonably foreseeable projects in the vicinity (preferably using georeferenced spatial data);
- Information about the regional context of the project area, including LRMP categories (to determine conformance, project acceptability, and appropriate mitigation), other local or regional level plans, valued components, issues, hot spots, trends in environmental features of interest, and other information. Much of this information is contained within the regional assessment (Section 3) and associated regional database; or, can be obtained from other maps and data;
- Knowledge of project-specific assessment tools and techniques, specific to the type of project being proposed. Guidance for project-specific assessments for four types of projects (seismic, exploration, production, and pipelines) is provided in the Oil and Gas Project Assessment Matrices (Appendix F); and
- Knowledge of the range and types of EMMs available to address project related effects at both the project and regional (i.e., joint management) levels.

To complete an advanced screening, similar information is needed although more extensive analysis and a finer level of detail are required to determine specific project effects and their significance.

It is imperative that new information collected at the screening stage (both routine and advanced) be integrated into the regional database and made available to other reviewing officers and land managers.

4.2.3.5 Roles and Responsibilities

Applicant

Project proponents are those who submit project applications and, by nature of their applications, conduct the first level of assessment of project-specific and regional cumulative effects. Their involvement is focused on individual applications; however, they play an important role in addressing regional cumulative effects by taking measures to reduce the effects of individual projects and by participating in higher-level (i.e., regional) effects management initiatives. Within the context of the regional strategy, the roles and responsibilities of proponents are:

- preparing and submitting an application, including proposed mitigation and monitoring;
- calculating their contribution to regional thresholds (if available);
- assisting OGC staff in understanding the proposed project by meeting information requirements;
- completing an advanced screening (if necessary);
- implementing conditions of project approval (i.e., follow-up); and
- potentially joining and/or funding (either voluntarily or by requirement) new or on-going joint or regional effects management initiatives.

Oil and Gas Commission

The OGC, and specifically OGC resource officers and managers, play a critical role in addressing cumulative effects at a project-specific and regional level. Their principle roles and responsibilities are:

- defining clear information requirements and application guidelines for project proponents;
- screening or reviewing project applications using all available information and resources;
- requesting new information and facilitating incorporation of new information into the regional database;
- applying criteria on evaluating contributing effects based on results and tests from resource planning (e.g., hot spots, thresholds);
- providing guidance to proponents who are required to complete an advanced screening;
- exercise their decision making duty (either routine or advanced) based on the available information;
- recommending management responses and conditions for reasonable and appropriate mitigation and monitoring, some which would need to be performed jointly; and
- monitoring (for compliance, enforcement and verification of predicted effects) as follow-up activities of the proponent's application, as applicable.

OGC Advisory Committee

The OGC's existing Advisory Committee is composed of members of various groups (environmental, government, First Nations, oil and gas, and public) to facilitate the contribution of consultation to the OGC's efforts. The proposed role of this committee in

ACES is to advise the OGC on matters relating to specific applications referred to the Expanded Review process. The nature of the advice sought includes identification of possible further actions required, such as assessment or effects management.

First Nations and Referral Agencies

In addition to the OGC, First Nations and regulators from other government agencies may be asked to review project applications. Their role in addressing cumulative effects at the screening stage is therefore similar to that of OGC staff. Specifically, this includes:

- reviewing project applications vis-à-vis their mandate and responsibilities;
- contributing to knowledge of the regional land base including activities (occurring or proposed) that may interact with the proposed project and potentially result in cumulative effects;
- making recommendations for regional mitigation and monitoring; and
- liasing with and participating on the proposed Regional Steering Committee.

4.3 Role of the Regional Assessment

The Regional Assessment (presented in Section 3) provides direction for scoping individual project reviews, and assists in identifying broad regional trends for land and resource use planning. Specifically, the Regional Assessment addresses the following critical aspects of the SRMS in the study area:

- **Regional Baseline**: using maps, the regional baseline describes the current state of selected land use and environmental features;
- **Issues:** identifies environmental features of concern, valued ecosystem components (VECs), current stressors, and possible future trends. These are done for the five environmental disciplines and the one land use discipline; and
- **Hot spots:** highlight possible areas of concern for specific environmental features. These are done for selected VECs within each discipline.

Collectively, these three sources of information can be used to provide the near equivalent of a State of the Environment (SOE) summary for the study area, based on the following observations:

1. What is the current environment and land use setting?
2. What are the environmental features of concern, and why?
3. Where may there be a problem for a certain environmental feature?
4. What are the possible future trends?

Of practical necessity, the resolution of the map-based information is coarse and not adequate to meet the needs of describing local conditions around specific projects; however, the information is adequate to identify existing and probable cumulative effects risks in the study area.

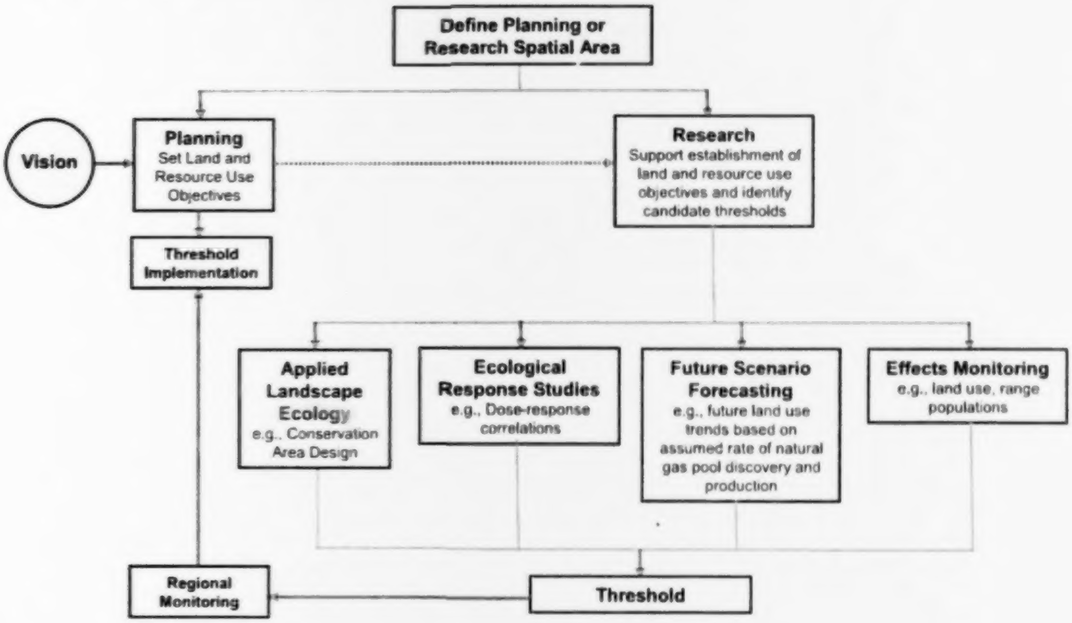
4.4 Role of Regional Planning and Research Studies

4.4.1 Overview

Regional planning and research studies (Figure 4-5) are used to further the understanding of the relationships between human disturbances and the environmental effects they cause, and to provide further information in support of the assessment and management of cumulative effects.

Responsibility to coordinate, facilitate and resource these initiatives typically rests with government given the scope of such efforts; however, industry can be involved in its development or eventually possibly become a key leader in its implementation. These initiatives are geographically broad, typically take many years (particularly those involving field work), require certain expertise, and require a central repository of updated information. By their nature, these initiatives fall under the land and resource management responsibilities of provincial government departments. The OGC can be involved as an observer and on an advisory basis, and would be able to provide information (such as updated land use information) while also benefiting from this work as part of its application review process.

Figure 4-5. Regional Planning and Research Studies


Define Planning or Research Spatial Area
Vision
Planning
Set Land and Resource Use Objectives
Research
Support establishment of land and resource use objectives and identify candidate thresholds
Threshold Implementation
Applied Landscape Ecology
e.g., Conservation Area Design
Ecological Response Studies
e.g., Dose-response correlations
Future Scenario Forecasting
e.g., future land use trends based on assumed rate of natural gas pool discovery and production
Effects Monitoring
e.g., land use, range populations
Regional Monitoring
Threshold

4.4.2 Regional Planning

Land use planning is used to establish vision and objectives for a region, a vital precursor to the establishment of thresholds. Typically, a vision and objectives are defined for a specific administrative area within which certain restrictions may apply to some uses, and certain management practices are identified. Planning thus begins the process of establishing the context in which cumulative effects can be measured, and in which the state of a region and the pace of change can be judged as acceptable or not.

In northeast BC, land use plans such as the LRMPs, local area plans, pre-tenure plans, and the SRMPs (as described in Section 2) provide a useful start in the identification of these goals.

4.4.3 Research

An important component of the SRMS is research that provides information necessary for understanding impact mechanisms and interactions, defining thresholds, and employing best management practices and adaptive management principles.

Research themes that will, over time, most directly advance the assessment and management of cumulative effects (e.g., development of thresholds) include landscape ecology, ecological response studies, future scenario forecasting, and monitoring. Each theme is described below, and current initiatives are briefly described that advance the development of thresholds.

4.4.3.1 Applied Landscape Ecology

Landscape ecology is the study of how spatial patterns affect ecological processes across the landscape. Knowledge of landscape ecology can help managers effectively maintain heterogeneity across the landscape by using and applying the principles of ecology, wildlife biology, cultural anthropology, land use planning, and economics. Limiting factors (e.g., habitat and breeding requirements, predator-prey relationships, traditional lifestyles) are identified and then used to clarify what is needed to maintain ecosystem structure and function across the landscape.

Several research efforts within the MKMA are already applying the principles of landscape ecology to develop insights into managing cumulative effects. These include:

- classifying species according to their similar feeding and breeding habitat requirements. Key representative species are selected for each life form and are then monitored to determine if feeding and habitat structural components can be used to monitor biodiversity over the landscape;
- developing a conservation area design (CAD) through species-based connectivity analysis. Attempts will also be made to integrate cultural importance; and
- studying ecological processes such as predator-prey dynamics and fire to develop a design to maintain habitat connectivity.

Although these initiatives do not explicitly develop management thresholds, they do provide a link between landscape level objectives (e.g., habitat connectivity) and local level decision-making (e.g., pre-tenure planning processes) that can substantially contribute to the development and verification of thresholds. Understanding these ecosystem processes will assist in identifying where (or when) certain developments should not occur.

4.4.3.2 Ecological Response Studies

Ecological response refers to the reaction of one or more ecosystem parameters to a stress or disturbance. Ecological responses occur with both natural and human-induced disturbances. In the context of developing thresholds to manage cumulative effects, these studies provide information that suggests acceptable limits of change to human-induced pressure. Dose-response models are currently being developed in Alberta that quantitatively describe human activity over ecological spatial scales, and is then correlated with species occurrence. This ultimately provides an index of cumulative effects that is capable of capturing a wide range of industrial activities over the landscape.

One research initiative (The University of Alberta's Integrated Landscape Management Program) is applying the principles of ecological dose-response to develop an understanding of the different spatial scales at which ecosystem processes are being disturbed. This represents an attempt to move away from the umbrella species concept towards an approach that includes more species from different taxa into an aggregated index. The index is correlated with industrial activity to form a surrogate of factors that pressure wildlife populations. For example, responses of passerines to different types of human disturbances at different spatial scales are being identified using this methodology. This information may prove useful in managing cumulative effects by providing information on the spatial scale that is most suitable to direct management efforts.

4.4.3.3 Future Scenario Forecasting

Future scenario forecasting involves the prediction of future conditions and occurrences based on how we believe an ecosystem will function under different management regimes. Future scenario forecasting allows managers to weigh the pros and cons of a desired land use condition. This is also a strategy to manage the risk of being caught off-guard by what the future might hold (e.g., uncertainty surrounding issues such as climate change can be explored).

A Landscape Cumulative Effects Simulator

The Alberta Northern East Slopes Sustainable Resource and Environmental Management Strategy (NES Strategy) provides an example of how future scenario forecasting is being applied to strategic land use planning with the long-term objective of managing cumulative effects. This forecasting is being conducted with a model called ALCES (A Landscape Cumulative Effects Simulator), a landscape accounting tool that can contribute to cumulative effects management by proving a mechanism for integrating information from different resource sectors, and creating linkages to more specialized decision support tools (Hudson 2002).

In the NES case, each sector and conservation interest (e.g., forestry, oil and gas, agriculture, conservation biologists, and water resource managers) define and run their own future scenario forecasting models (e.g., energy model, forestry model, population models, water basin models), which are then integrated using ALCES. It is hoped that this approach will build trust among industrial and conservation interests as all inputs to the forecasting model are analyzed using the same tool, thereby creating a more level playing field among sectors. Tools such as ALCES can also be useful in the development of thresholds; for example, ALCES is capable of quantifying the rate of land use change, and correlating changes in specific habitat or population variables.

Ultimately, from the land and resource manager's perspective, use of these tools provides the following information that may assist their planning and decision-making:

- the time period (i.e., years) before a resource of management concern reaches an unacceptable state (e.g., it will take 16 years before the regional moose population may decrease below minimum viable population). As such, the level and timing of a management response can be designed proportional to the predicted time remaining to head off a management issue of concern; and

- the degree by which various effects management measures will alter the above time period. For example, an 'as-is' scenario likely will result in the resource being of concern sooner than if a comprehensive suite of management practices were exercised. As such, the manager can choose an optimum effect management approach given the availability of time and budget.

Global Methodology for Mapping Human Impacts on the Biosphere

The Global Methodology for Mapping Human Impacts on the Biosphere (GLOBIO), developed by the United Nations Environmental Programme (UNEP), is based on quantifying species response to human disturbances. It aggregates the responses of many species to access disturbances (based on the conventional concept of alienation buffers). This concept currently serves as a major part of most EIAs that include wildlife assessments. What is new is the intent to gain acceptance of this approach at very large landscape scales, based on coarse land use and species response descriptions. This then supports mapping of large regions (typically based on satellite imagery interpreted to describe land use and environmental features), such as an entire province, which at a gross landscape level can indicate degrees of alienation that are attributable to the incursion of human access (i.e., roads) into wildlife habitat. If the base mapping is available over long periods of time, 'snapshots' can be taken of these conditions over many years to visually show the progression of human effects on wildlife. This reflects what is typically the single greatest contributor to cumulative effects anywhere in the world; namely, the continued expansion of roaded access, particularly new access into unroaded hinterland areas.

The advantage of GLOBIO is that it provides a relatively quick and inexpensive means of assessing cumulative effects over very large geographic areas. The disadvantage is the uncertainty associated with interpreting its results given the highly coarse spatial mapping scale and the gross aggregation of species response (e.g., general disturbance coefficient for birds) to simplified access descriptions.

This approach was recently used by Canadian Arctic Resources Committee (Cizek, McCullum and Booth 2002) to map cumulative effects in the Fort Liard region of the southwest Northwest Territories (immediately north of, and adjacent to, the northeast BC CEAMF study area). The land use pressure of concern was oil and gas exploration and production. This study quantified human activities (e.g., oil and gas tenures, well sites, pipelines, all weather and seasonal roads) in a 100 km^2 radius around Fort Liard at four points in time. The study's conclusions were based on the percentage of landbase that is increasingly alienated to wildlife over a 50-year period. For example, in the year 2050 (with the level of oil and gas activity extrapolated from current trends), approximately 30% of the study area would be considered to have a high risk of effects on plants, animals and food chains. It is highly likely, however, that such model results are overly conservative if the recovery of disturbed areas over such extended periods of time is not included.

4.4.3.4 Effects Monitoring

Monitoring refers to repetitive measurement of a variable consistently and over a long period of time (Beanlands and Duinker 1983). It is a fundamental part of any land and resource management strategy. Monitoring can be used to update land and resource information, confirm compliance to approval conditions, confirm the application and effectiveness of effects management, and verify predictions of effects. Ideally, monitoring is used to validate and modify thresholds, and to quantify ecological parameters to ensure that land use pressures do not induce an ecological response that exceeds a threshold. In the absence of thresholds, monitoring is used to quantify ecological response and land use trends. As changes in ecological responses become correlated with changes in land use trends, thresholds materialize.

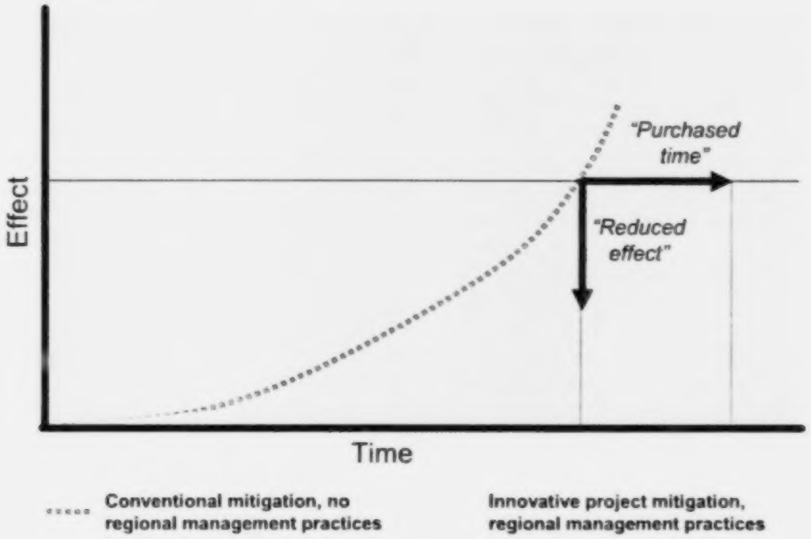
4.5 Role of Effects Management

4.5.1 Overview

The SRMS relies on two principle techniques to manage effects: effects management measures (EMM); and thresholds. The first technique has the benefit of including options that are already implemented and can be recognized as contributing to the management of effects. Another benefit is the potential use of numerous further options that can be readily implemented, or implemented with a reasonable application of current proponent and/or government resources. The second technique has the advantage of truly addressing cumulative effects over large areas that are subject to numerous land use pressures.

In the absence of thresholds, the role of effects management is to do the best that can be done to buy time by slowing the pace of an adverse environmental effect (Figure 4-6), time that can be used to progress other regional initiatives, especially the implementation of thresholds (the ALCES simulations in Volume 2 are an example of this). Therefore, the more effective the EMMs, the longer the time before an unacceptable level of effect is reached (if ever). The default 'as-is' approach to EMM is accelerated for terrestrial and some aquatics effects in situations where there is continuing net environmental degradation caused by reclamation that cannot compensate for continued disturbances.

Figure 4-6. Implications of Effects Management on Pace of Environmental Change



Ultimately, the CEAMF concept, as interpreted in this report, emphasizes the "M" for management over the "A" for assessment as the most important contributor to the success of the framework; hence, the SRMS's explicit inclusion of management in the name. The basis for this is the practical and both immediate and long-term benefit of the contribution of management practices. Although assessment has and should continue to play an important role, in the end it often does a better job in identifying potential effects than evaluating how important (i.e., significant) many effects may be.

This view is also an application of the precautionary principle, which essentially states (in the context of this discussion) that we should move ahead and apply effects management even if we are not absolutely sure of what environmental effects are happening, and how they are happening.[5] As such, what we can learn from assessments, and in recognition of what we do not know or are unclear of, should not necessarily give reason to deter management measures under the excuse of uncertainty. That said, the onus then on decision makers is the responsibility to ensure that a reasonable standard of understanding (scientific or otherwise) is investigated prior to implementing the principle.

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[5] Likely the most commonly used definition of the precautionary principle, and adopted by the Government of Canada, was developed in 1992 during the United Nations Conference on Environment and Development (as part of the Rio Declaration, or Agenda 21), which states: *In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*

4.5.2 Types of Effects Management Measures

The first and most important step for managing cumulative effects is to manage where those effects start; namely, at each of the individual projects that contribute to effects. Some EMMs can reasonably and non-onerously be the responsibility of individual project proponents. Some of these measures may be conventional, some best practice, and some innovative.

However, in some cases these project-specific EMMs may not be adequate, and a meaningful contribution to managing effects can only be accomplished through jointly coordinated efforts with other operators who share contributions of effects to common environmental features.

Furthermore, some measures are only reasonably supported and coordinated by government. These typically involve many years of effort, the collection and organization of large amounts of regional data, and the formulation of public policy. Such measures are not directly tied to one specific project, but reflect the on-going contributions of many forms of human disturbance over large areas for many years.

In summary, EMMs can be categorized into three types:

- **project-specific**: applied only to an individual project, and are the responsibility of that project operator subject to government requirements and best practice;
- **joint project**: applied to multiple projects by multiple operators, and are jointly coordinated amongst operators with government participation; and
- **regional**: applied over a large geographic area, independent of requirements for any project, and are implemented by government with industry participation.

There already are many management techniques being implemented in northeast BC. Some of these and others are gaining wide acceptance and implementation in other jurisdictions (such as Alberta)[6], all of which are readily adaptable to BC. Table 4-1 identifies 29 EMMs for the three types explained above.

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[6] For example, three of the EMMs identified in Table 4-1 (Integrated Landscape Management, Constraints Mapping and Low Impact Exploration) have been adopted for voluntary compliance by all members of the Athabasca Oil Sands Cumulative Effects Management Association (CEMA). A detailed description of these measures are provided in AXYS and Lormel (2002), downloadable from www.axys.net.

Table 4-1. Effects Management Measures

Level	Project	Joint Project	Regional
Lead Role	Individual Operator Subject to Government Requirements[1] and Best Practice	Jointly Coordinated Amongst Operators with Government Participation	Government with Industry Participation
Options	Codes of Practice	**Development Plans**[3]	**Conservation Area Design**
	Conservation and Reclamation Plans	**Integrated Landscape Management**	**Future Scenario Forecasting**
	Constraints Mapping	**Trunk Road Coordination**	Indicators (for monitoring/thresholds)
	Construction Best Practices		Local Area Plans
	Environmental Protection Plans		**Pre-tenure Plans**
	Forestry Operations/Management Plans		Protected Areas Strategy
	Geophysical Operating Guidelines		**Regional Access Management**
	Geophysical/Environmental Field Reports		Regional Ecological Monitoring
	Low Impact Seismic		Regional Spatial Databases[4]
	Minimization of Clearing		Regional Plans and Zoning
	Planning and Engineering Design		Regional Thresholds
	Setbacks[2]		Resource Management Plans[5]
	Timing Windows		SRMS Steering Committee

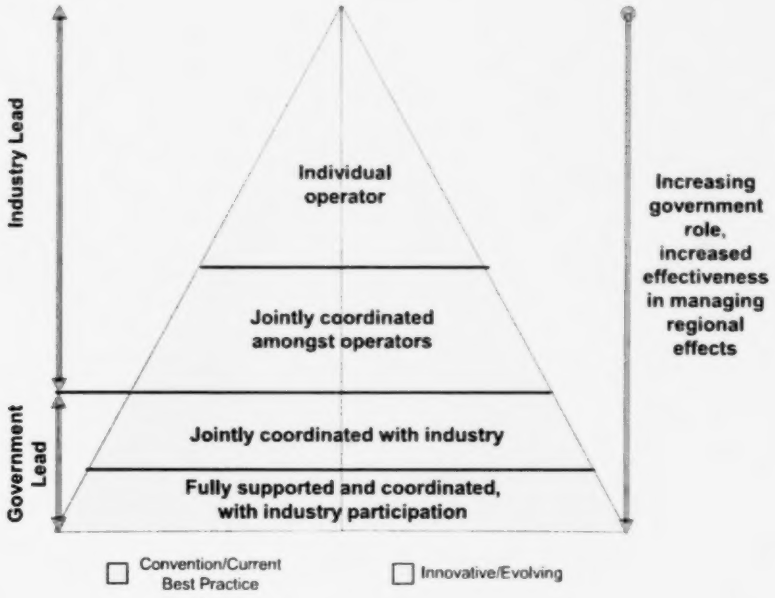
Notes:
1. For example, as described in the *BC Oil and Gas Handbook*
2. Provided in current OGC Minimum Disturbance Criteria
3. Provided in current OGC General Development Permits
4. Includes land use and environmental features
5. Includes species range management

Bolded options are relatively new, innovative, and still evolving

Selection of the most appropriate EMMs is based on the particular circumstances involved; selection therefore must be done on a case-by-case basis. Factors involved in a selection include the nature of the projects, their effects, mandatory measures (as part of statutory requirement) and any voluntary measures for that region.

This organization of management measures is further illustrated in Figure 4-7. Initiatives at the base of the triangle provide the broadest and most comprehensive contributions to the management of effects, but with a smaller range of options. The peak of the triangle provides options applicable to individual projects or collections of projects that are more often implemented many times. Each level, therefore, contributes in its own way to addressing cumulative effects. In the current BC context, the proportion of government led efforts is decreasing while the proportion of industry led efforts is increasing as expectations change to have industry take more of a lead role.

Figure 4-7. Levels of Effects Management Measures


Industry Lead
Government Lead
Individual operator
Jointly coordinated amongst operators
Jointly coordinated with industry
Fully supported and coordinated, with industry participation
Increasing government role, increased effectiveness in managing regional effects
☐ Convention/Current Best Practice
☐ Innovative/Evolving

It is useful to note that some initiatives not commonly viewed as effects management techniques are, in fact, major contributors to managing effects at large landscape scales. Protected area strategies (approximately 9% of the CEAMF study area has a protected status) and conservation area designs are examples of these. Their contribution to managing effects is through the planned removal of some areas from all or some types of development, thereby providing areas that are secure from human-induced change, while allowing change to occur elsewhere.

In summary, there are many levels at which effects management may occur, based on involvement by one or more project proponents, and one or more reviewing bodies working either alone or in combination (e.g., industry alone, industry working with government, or government alone). The usefulness of these techniques improves with greater collaboration and with broader regional perspective.

4.5.2.1 Broadening the Collaboration

Related to government responsibility is the need to involve more than one government department, ministry, or agency during project reviews or planning if cumulative effects are to be addressed. For project-specific reviews for the oil and gas industry, the OGC's provision of a one-window application process would, at first, appear to preclude such involvement. At second glance, the referral process suggests an opportunity to at least request comment by other external parties; however, the exigencies of processing so many applications likely would not make this practical, except in the occasional unique circumstance.

Furthermore, as expressed by the intent of joint project EMMs, the participation of other project proponents would further broaden the scope of effects management, and therefore increase the success of such measures. Also, other proponents could be involved with overlapping interests, including oil and gas operators, and possibly those from other sectors (such as forestry).

An opportunity possibly exists to broaden the scope of the EMMs, and ultimately, make them more effective, through expansion of the current development plans supported by the OGC; namely, the General Development Permit (see Section 4.5.3.2), for which a proponent must disclose the full intent of their plans regarding exploration and production of their oil or gas tenures. Such plans currently only apply to one project proponent.

Table 4-2 summarizes the full scope of opportunity, indicating six levels of review. Starting with conventional individual project applications reviewed by a single reviewing body, the table moves on to development plans involving either more operators, more reviewers, and ultimately, more sectors (e.g., energy and forestry). Each next option (identified by a number) provides, incrementally, a more comprehensive contribution to managing cumulative effects.

As to how far one needs to go in applying an effects management response beyond the minimum, as dictated by standard convention, will first depend upon the degree to which a given project is contributing, along with other projects, to a clear effect of concern (as indicated in Step 3 of ACES as shown in Figure 4-4). Such conditions can arise, for example, at the discretion of the OGC, in a relatively confined or local area, such as a river valley or natural gas pool in which access by many operators is desired. An appropriate effects management response may include a coordinated plan to share a common trunk road access, at least as long as possible, while still providing the opportunity for individual operators to eventually access their respective leases.

Table 4-2. Managing Effects as Single Applications and Under Development Plans

	Number of...			Option	Description
	Proponents	**Use Sectors**	**Reviewers**	**#**	
Single Application	One	One	One	1	Current convention for all projects
			Multiple	2	Additional issues possibly identified
Development Plans	Multiple	One	One	3	Identification of full build-out
			Multiple	4	Inclusion of other overlapping or nearby projects
	Multiple	Multiple	One	5	Inclusion of other operators
			Multiple	6	Inclusion of full disturbances by all projects

Note: Option 3 is the level of the OGC's current General Development Permit

4.5.3 Description of Effects Management Measures

The following provides a brief description, in alphabetical order, of each level of the EMMs identified in Table 4-1, with a focus on how they apply to oil and gas activities.

4.5.3.1 Project

Codes of Practice: A code of practice is a tool that provides guidelines on how industry should conduct business on the landscape at a level specified in legislation. For example, the OGC's Maximum Disturbance Review Criteria (MDRC) Operating Code provides guidelines for oil and gas construction contractors and service firms. The results-based code of the *Forest and Range Practices Act* provides guidelines for the forest industry that are applied provincially.

Conservation and Reclamation Plan: Conservation and Reclamation (C&R) Plans are designed to return conditions at a project site to their pre-disturbance state following decommissioning. These plans deal with the removal of equipment or buildings, decontamination of buildings or other structures, stabilization, contouring, maintenance, conditioning or reconstruction of the surface of land, or any other related procedure, operation, or requirement specified in legislation.

Constraints Mapping: Constraints mapping illustrates where valued land and water features occur within a project area so that proponents can substantially reduce some environmental and cultural effects. Constraints maps are generated by first developing a map of environmental and cultural sensitivities (e.g., key overwintering habitat, and aboriginal gravesites), which are then translated through a numerical weighting process to indicate a certain degree of constraint of the project siting (AXYS and Lornel Consulting 2002).

Construction Best Practices: Construction best practices are measures a proponent takes beyond convention. The development of construction best practices should take into account the unique characteristics of the landscapes affected.

Environmental Protection Plans: Environmental Protection Plans (EPPs) are similar to C&R plans in format, but contain a briefer environmental overview and description of mitigation to potential environmental issues. EPPs are an effective tool for proponents to implement best practices and operational guidelines (developed in their planning phases) in the field during construction and abandonment phases of their projects.

Forestry Operations and Management Plans: Under the results-based forest and range practices regime for BC, forestry operations and management plans are developed by industry, and overseen by government using guidelines from the *Forest and Range Practices Act*. Forestry Operations and Management Plans in BC must be in place before industry can obtain Resource Development Permits (RDP) to cut and develop roads. Based on these plans, the Ministry of Forests monitors the effectiveness of industry in achieving sustainable forest management.

Geophysical Operating Guidelines: Geophysical Operating Guidelines are a set of land use expectations (i.e., operating guidelines) set forward by the provincial government for geophysical (seismic) operations. For example, BC requires a geophysical exploration program be prepared in relation to factors such as wildlife and habitat disturbance, destruction of forest cover, protection of streams and rivers, erosion prevention, site and restoration. Final project plans must be prepared showing the location of all roads, trails, and cutlines that were used or made, the location of each shot point, and the location and size of campsites and landing strips. All construction and changes in construction must be approved. The guidelines address operating procedures, including those camps and relationships with trappers in the area, and also set out general restoration requirements.

Geophysical/Environmental Field Reports: Typically, a geophysical or environmental field report is a compulsory part of the application approval to conduct a geophysical exploration program; thereby, proponents exercise due diligence by requiring identification of significant environmental resources. The process of identifying significant environmental resources prior to application approval in the MKMA is the pre-tenure planning process (PTP), which allows industry and government to identify desirable and appropriate locations for exploration while also considering other values.

Low Impact Seismic: Low impact seismic (LIS) minimizes line width (e.g., 1 m to 4.5 m, not to exceed 5 m), minimizes the line-of-sight of seismic lines (e.g., to less than 200 m), and avoids standing timber while minimizing disturbances to soil and vegetation ground cover. LIS was developed to reduce the amount of timber lost to seismic line construction and to reduce the cost of the related timber damage assessment.

Minimization of Clearing: Minimization of clearing simply refers to reducing the amount of land disturbed or lost as a result of a project (e.g., removing vegetation and habitat, both for wildlife and fish), and thus, helps maintain core security and edge habitat, maintain connectivity, and reduce corridor widths.[7] Minimization of clearing can be accomplished by planning, engineering, and construction practices that reduce the footprint of a project and its individual components (e.g., for well pads and fence lines), and that employ best construction practices on a site-specific basis. The OGC Information Letter (IL) 02-08 acknowledges the benefits of minimization of clearing, and encourages it as part of its policy on Environmental Upgrade Notice.

Planning and Engineering Design: Reduction of ecological disturbance and fragmentation can be accomplished through engineering features such as minimizing the graded surface of RoWs, reducing the number of surface facilities, and controlling noise, dust, and light. Development plans also reduce ecological disturbance and fragmentation by identifying beforehand, where the project footprint will occur, and by consolidating the footprint as much as possible. Related to planning is conformance to project siting restrictions; for example, outright exclusion from entry into certain areas, or default minimum well spacing requirements (e.g., in the Peace River District, 1 gas well per section and 1 oil well/quarter-section).

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[7] The concept of no-net-loss is often raised as an option to broadly address cumulative effects, based on the principle that if a land or riparian area is disturbed, another area of equivalent geographic extent and/or function would be constructed to offset the project's effects. Although this technique may be successful in some circumstances, its ability to ultimately contribute to addressing cumulative effects is handicapped by two factors: i) the approach assumes the availability of another area to do this, which may not always be the case, especially in areas under intensive development and with private lands; and ii) any such efforts typically will only maximize benefit for only one or a few selected species, and not necessarily for the full suite of species originally ecologically dependent on the new site.

Setbacks: A setback is a mandatory distance that a project component or construction-related activity must be from an environmental feature. Such features are typically water bodies and niche wildlife habitat. As specific examples, the OGC requires a 200 m minimum construction setback from a Trumpeter Swan nest, and the Ministry of Forests requires that a well site edge must be set back from the breaks or banks of classified streams and water bodies (OGC 2002).

Timing Windows: Timing windows are periods of time within certain geographic areas in which all, or specific activities may not occur. For example, forest practices are subject to timing windows for stream crossings based on the migratory behavior of fish.

4.5.3.2 Joint Project

Development Plans: Development Plans are an approval in principle for oil and gas activities and pipelines in a local area, allowing for concurrent examination of the surface effects of oil and gas activities and pipelines in that area. The OGC's version of this, the General Development Permits (GDPs), have recently been formed after amendments to the *Oil and Gas Commission Act* and the *Petroleum and Natural Gas Act* in what is now known as Bill 36, the *Energy and Mines Statutes Amendment Act* (2002). Development Plans also are a requirement (EUB IL 93-9) for applications submitted before the Energy and Utility Board (EUB) in Alberta's Southern Eastern Slopes region.

Integrated Landscape Management: Integrated Land Management (ILM) reduces the industrial footprint over a landscape through the coordination of industrial and conservation activities. For ILM to be effective, infrastructure development plans, resource extraction activities, and other ILM concepts must be identified early in a project's life. Proper pre-planning, preliminary analysis, and identification of stakeholders with similar interests or common needs are essential to the ILM process.

Trunk Road Coordination: Trunk road coordination refers to the collaborative planning process that must take place among industrial players to effectively accomplish the goals of ILM. Trunk road coordination allows for both forest and energy sectors to share roads in the short and long term, and allows for the minimization of single-user access corridors as a means of reducing cumulative effects. The OGC IL 02-08 acknowledges the benefits of this to project applications as part of its policy on Review Corridors and Minor Changes to Approved Activities.

4.5.3.3 Regional

Conservation Area Design: Conservation Area Design (CAD) is a strategy for attaining specific conservation objectives through the use of landscape ecology principles. A CAD is currently (2003) being developed for the MKMA through species-based connectivity analysis. Ecological processes such as predator-prey dynamics and fire are being investigated to help develop a design to maintain habitat connectivity.

Future Scenario Forecasting: Future scenario forecasting involves the prediction of future conditions and occurrences based on the how we believe an ecosystem will function under different land use and effects management scenarios. Future scenario forecasting allows managers to weigh the pros and cons of a desired land use condition, determine the period of time before an unacceptable environmental condition is reached, and assist in identifying the degree of management effort required to prevent that condition from occurring.

Indicators (for monitoring and thresholds): An indicator is a quantified variable that describes or measures an environmental or social condition. It is imperative that indicators are realistically defined and consistently measured so that environmental and social conditions can be monitored on an on-going basis. To identify thresholds, the monitoring of selected indicators must be performed in conjunction with the monitoring of changes in land use. As changes in an ecological or social condition become correlated with changes in land use, it is apparent that a threshold is being reached.

Local Area Plans: In BC, local area plans are used to provide management direction for specific areas that fall under, and are consistent with, strategic objectives defined through sub-regional LRMPs. Examples of local area plans include park management plans, forest development plans, wildlife management plans, and oil and gas pre-tenure plans.

Pre-tenure Plans: A pre-tenure plan (PTP) is a local level planning mechanism that is used to guide the environmentally responsible development of oil and gas resources through the identification of objectives and strategies for development activities, and through compliance to specific EMMs. Currently, only Phase 1 of the Besa-Prophet PTP (in the MKMA) and the Upper Sikanni Management Plan has been developed, with other PTP processes scheduled for completion in 2003.

Protected Areas Strategy: A Protected Areas Strategy (PAS) outlines a strategy and defines objectives for creating and maintaining a system of protected areas. A PAS establishes the concept of ecosystem representation as the fundamental premise that guides the identification and selection of new protected areas. Strategic land use plans are the principle mechanism for reaching decisions on new protected areas under a PAS while local level plans (i.e., management plans) provide strategic direction of individual protected areas within the system.

Regional Access Management: Access management is usually accomplished through the use of various in-field measures such as gating, closures, and reducing ease of access (e.g., using berms and slash piles) along any otherwise accessible RoW. Regional access management is a coordinated approach at implementing these measures among all industrial proponents who would share common access in a region.

Regional Ecological Monitoring: Regional ecological monitoring quantifies ecological and social conditions at a landscape level. Parameters that are quantified at this scale are called indices, and they reflect a coarser level of monitoring. Examples of this type of monitoring include tracking of access road density.

Regional Land Use/Environmental Mapping Databases: Regional land use and environmental mapping databases are essential tools in the support of land use management. These tools assist in the dynamic tracking of land uses, and in incorporating environmental features collected from studies and monitoring support while implementing effects management tools.

Regional Plans and Zoning: Regional plans provide guidance for land use over a large land base. Sustainable Resource Management Plans (SRMPs) and Land and Resource Management Plans (LRMPs) are examples of sub-regional or regional plans. The plans make use of zones to define land uses, and they provide information about permissible activities. For example, within LRMPs, resource management zones (RMZs) provide general objectives and strategies for maintaining unique resources within the zone.

Regional Thresholds: A threshold is a quantified parameter that represents an unacceptable environmental or social condition. Maximum access densities or minimum core security patch size (i.e., area) are examples of thresholds that can be quantified at the regional level.

SRMS Steering Committee: A Steering Committee (not presently in place in northeast BC) is a group that reviews, critiques, and supports regional initiatives that promote the management of cumulative effects. A Steering Committee comprised of regional stakeholders provides a link between cumulative effects initiatives in a defined study area.[8]

Species Range Management: Species range management involves maintaining effective habitat for one species based on an umbrella species concept. For example, caribou populations are directly affected by loss of peat habitat, old growth habitat, and distribution of forest cover; therefore, caribou are often used as an indicator species of the overall health of boreal forests. A Wildlife Management Plan (such as for the MKMA) is an example of a broader management plan that addresses many species and habitat needs.

4.5.4 Details for Selected Regional Techniques

The following provides further description of three effects management options — integrated landscape management, access management, and development plans — that may, in many cases, prove to be the most effective and implementable in northeast BC. All of these are already in place, albeit currently in a limited but growing extent, in both BC and Alberta in direct response to forestry and oil and gas activities.

4.5.4.1 Integrated Landscape Management

Integrated Landscape Management (ILM) is used to manage regional cumulative effects by reducing industrial footprints on a shared landscape through the coordination of industrial activities and conservation efforts that are being undertaken by two or more proponents. The success of ILM depends upon the will of industrial proponents to collaborate and pre-plan infrastructure development and resource extraction activities at a landscape level.

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[8] The current Peace Managers Group performs, for example, some functions of the proposed Steering Committee, especially in resolving situations involving cross-jurisdictional issues.

Generally, there are two components of the ILM process that contribute to effects management. The first is the sharing of routes to gain access to resources of interest, thereby eliminating the need for each proponent to build their own road. Secondly, clearings are shared among proponents. For example, harvesting of cutblocks is coordinated with the placement of well pads over the landscape, thus eliminating the need for the oil and gas proponents to conduct clearing. The principle ecological benefits of ILM are reduced habitat fragmentation and maintenance of habitat connectivity.

Development plans (discussed in more detail below) that are coordinated among industrial users (e.g., use of shared access) may contribute to the success of ILM at planning stages.

4.5.4.2 Access Management

Access management is a conventional approach used to manage the effects of motorized vehicles along industrial access routes. Traditionally, access management techniques have included gating, closures, and reducing the ease of access through mechanisms such as berms and slash piles. Access management is already a priority in managing environmental effects in the MKMA. For example, the Besa Prophet Pre-Tenure Plan cites access management as "the most critical element in achieving the plan's goals for oil and gas activity in the MKMA" (BC MSRM 2002). In addition, the MKMA was originally designated under the *Wildlife Act* to restrict public off-road vehicular access to designated roads in order to protect wildlife habitat.

Coordination of trunk road access into still relatively inaccessible areas is an example of one emerging access management approach. An example of this is an industry-led initiative occurring in Chungo Creek, Alberta, that is undertaking proactive planning to reduce the impacts of industry (primarily oil and gas and forestry) at the landscape and project level. The process includes two main parts: an information letter (IL) and an environmental field report (EFR). The IL explicitly identifies discipline components (e.g., aquatics, wildlife) and corresponding guidelines to manage new access. The IL also points out new requirements for shared access, including early dialogue among proponents and reclamation of roads in a timely fashion. The EFR captures the results of the proponent's efforts to collaborate with other industrial players. For example, as one of the steps in the EFR, proponents must pre- and post-survey their communications with other industrial players and report their activities back to government land managers.

Research being conducted in the Athabasca Oil Sands Region of Alberta has led to the development of mitigation measures to reduce the effects of access on caribou. These mitigation measures include encouraging the use of hand-cut seismic lines and heli-portable seismic operations, complete roll-back of trees and debris onto seismic and pipeline RoWs, and prompt revegetation of linear corridors with native trees species, and limits to reduce industrial developments in woodland caribou habitat. It has been recommended that similar measures be adopted in the MKMA (Hawkes and Searing 2001).

Research being conducted by the Regional Carnivore Management Group, a research initiative operating in parallel to the NES Strategy in Alberta, is addressing the management of cumulative effects of access by calculating threshold and target values for assessing appropriate landscape conditions for grizzly bear (e.g., density of all weather roads over 0.3 km/km^2 has an adverse effect on grizzly bear populations). This work illustrates the link between threshold research and effects management of increased access due to industrial roads.

4.5.4.3 Development Plans

Development plans in general, and specifically those submitted as part of the OGC's General Development Permit (GDP) application, outline an approach to the management of the effects of multiple activities on the landscape. In this process, proponents are required to submit a plan outlining proposed access options, exploration drilling, and production and pipeline scenarios and options to the OGC before approval of any activity. The development plan is modified as new information on land use is gained. The development plan describes a proponent's build-out scenario assuming resource expectations are met. In this way, an approval-in-principle is provided that reflects the opportunity to reduce environmental effects by one proponent, or by multiple proponents planning to operate in an overlapping fashion on the land base or in close proximity to each other (such as occurs in the opening of a new gas field).

The proponent, for example, first demonstrates compliance with the land use objectives specified in a pertinent higher-level plan such as an LRMP. An Environmental Protection Plan (EPP) is then developed, which identifies mitigation measures such as minimizing clearing, conducting drilling programs and pipeline construction during winter months to minimize impacts on resident wildlife, implementing access control mechanisms such as gating, monitoring wildlife, and reclaiming roads.

Plans as part of forestry Resource Development Permits (RDP) may also be incorporated. Proponents in these permits must prove that old growth targets are met, cumulative hydrologic impacts are identified, and public issues and concerns are supported (Government of British Columbia 2002).

Prior to preparing the development plan, an environmental overview assessment is conducted to assist the proponent in responsibly planning a drilling and development program. The environmental overview includes a project description, methods used to gather information, descriptions and the significance of all biophysical factors, description of lands, First Nation's area of traditional practice, and recommendations to facilitate environmentally sensitive planning and development in the tenure area.

In Alberta, the EUB's IL 93-09 *Oil and Gas Developments Eastern Slopes (Southern Portion)* is another example of a development plan, one which recognizes planning at both the pool delineation and pool development stages.

4.6 Role of Thresholds

4.6.1 Regional Vision and Objectives

To properly assess cumulative effects, and to appropriately plan management of those effects, the desired state of environmental features must be known. Whether it is air quality for a community, depth of agricultural soil, or hectares of forest habitat for songbirds, the significance of an effect can only be determined through a well-educated guess in the absence of a clear understanding of what is an acceptable state of an environmental feature, and inversely, what is an unacceptable state.

Sustainability (as introduced in Section 4.1.2.1) and land use planning (as discussed in Section 4.4) can contribute to the identification of a regional vision and objectives; however, in most cases, these goals as expressed are too broad to be used as thresholds. In these plans, the objectives and guidelines consist mainly of recommended EMMs subject to voluntary compliance, and not ultimate land use goals expressed as a measurable target (e.g., a maximum number of hectares that can be cleared for specific types of conventional projects such as access roads).

Generally, what is needed are specific limits or thresholds for certain environmental features. To be useful, thresholds must be quantitative, that is, represented by a measurable number. Regional visions and objectives, as expressed through plans, provide an interim step towards a defined limit of acceptable change.

4.6.2 Implementing Thresholds

4.6.2.1 Challenges to Implementation

The significance of the contribution of an individual project to an environmental effect may generally be judged most easily as follows, referred to here as the 'thresholds test'. For a given area and environmental feature of concern:

- If the project's contribution to the effect (for that feature within that area) does not cause an exceedance of a threshold, then the project's contribution to cumulative effects is acceptable (e.g., not significant).
- If the project's contribution to the effect does cause an exceedance, then the project's contribution is not acceptable (e.g., significant).[9]

However, regulatory (mandatory) thresholds currently exist only for a limited number of environmental components; mainly air and water-borne physical constituents. Some thresholds for biological features such as wildlife and fish do exist, typically as guidelines; however, they are limited in their direct application to address broad (i.e., landscape scale) cumulative effects issues. Environmental management techniques such as setbacks, as expressed, for example, in the OGC's Minimum Disturbance

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[9] One possible exception is the interpretation of significance where thresholds have already been exceeded (e.g., in areas already substantially compromised). The question then becomes if the addition of another project makes any difference, assuming that at least, various forms of effects management and monitoring are already in place.

Criteria, are not land and resource use thresholds. Some thresholds reflect social views (e.g., recreational limits of acceptable change).

Thresholds are not necessarily readily implementable until certain initiatives are completed (Volume 2). There are many examples of what could be used to define those missing thresholds based on scientific research, the better of which is based on empirical study (i.e., field research). Once translated into a practical implementation process, they can be used to guide decision-making both at the individual project and regional landscape level.

Before being implemented, thresholds must have the advantage of at least being proven to be reasonable and based on accepted science and traditional observation. They must, therefore, be robust and defensible prior to implementation in a regulatory review process in which the fate of applications includes a thresholds test. To do so is a challenge, for herein lies the meeting point between the interpretations of science versus administrative process. Given the considerable uncertainties associated with thresholds based on ecological response or land use, an overriding justification for implementation of thresholds is required based on another interpretation; namely, of regulatory mandate (in the case of the OGC), and mandate as regards land and resource use management (in the case of provincial ministries).

To do otherwise will inevitably lead to the day when a restriction or outright rejection of a project application will be required to meet a threshold's conditions, a situation for which there is no known precedent for non-regulated environmental features. Such a decision, although in keeping with the intent and spirit of thresholds, likely would be challenged by the project proponent. Subsequent jurisprudence may fall in favor of the proponent unless mechanisms are clearly in place to resolve such conflicts arising from the thresholds test; and, good science supports the thresholds. Conversely, decisions in favor of government could be based on use of the precautionary principle in that the implementation of best management practices (i.e., thresholds, in this case) should not be delayed under the excuse that not enough is known about an effect.

4.6.2.2 Decision Options

Given the above challenges, a means of resolution must include an opportunity to engage the applicant in examining project-specific and joint project EMM options, while initiating or becoming part of a parallel regional initiative (such as regional monitoring). The latter route is commonly used in Alberta's Athabasca Oil Sands, in which project proponents apply project-specific EMMs while deferring some or all measures for managing cumulative effects to the on-going CEMA initiatives (jointly funded and co-ordinated by industry themselves; see Appendix B). This omnibus approach to the management of cumulative effects, which currently includes preparatory work for air- and water-based thresholds, presents an option to proponents, especially in areas of intensive development where collaborative CEMA-like processes are more reasonably effective and supported.

This, therefore, suggests the following possible range of options for the fate of applications before the OGC given implementation of a thresholds test:

- approval — no project contribution to a threshold exceedance;
- approval with standard conditions (i.e., those already required and in common practice);
- approval with exceptional conditions (i.e., those specifically required to address cumulative effects). Prior to this decision, the applicant will be provided an opportunity to discuss the nature of their commitments with the OGC. If matters are not resolved, the application could be referred to mediation; or
- rejection.

4.6.2.3 A Threshold Implementation Strategy

Volume 2 provides a detailed description of the theory and practice of thresholds, concluding with candidate thresholds for northeast BC and a proposed implementation process. In summary, three sets of cumulative effects thresholds are presented: generalized road density (based on road and trail densities), generalized core area, and species-specific thresholds for caribou (based on corridor density). For each type, thresholds are proposed as they related to three LRMP land management categories: enhanced resource management areas; general resource management areas; and special resource management areas.

A project's contribution towards each threshold is calculated and compared to three tiers of numerical thresholds — cautionary, target, and critical — each successively reflecting a greater degree of concern.

In this way, the degree of contribution of individual projects to thresholds within each RMA can be used to test that project's acceptability to regulators. The result also provides an update on the regional status of land use and effects within each of the three types of land management categories, which in an adaptive fashion can be used to provide a better understanding on a landscape scale (i.e., regionally) of the:

1. state of land use or habitat indicators that represent cumulative effects concerns;
2. pace at which the next threshold for that indicator may be approaching; and
3. need for enhanced environmental protection measures and monitoring.

A future scenario forecasting tool (such as ALCES) may be used to evaluate possible future trends for an indicator or species of concern, to evaluate economic tradeoffs, and to suggest the time period before a management point of concern is reached.

In the proposed implementation process, project proponents would submit, with their OGC application a calculation of the contribution of their project relative to the thresholds. The intent is that these calculations would be standardized, quick and non-onerous. For example, construction of a wellsite access road would cause an incremental increase to access densities in the resource management zone in which it is proposed. The combined density would be compared to established thresholds. Once approved, this development would be added to the database and included in future calculations.

What then follows (as shown in Figure 4-4) is that projects in areas with low to moderate cumulative effects hazard (i.e., below cautionary and target thresholds) are subject to project-specific and joint project EMMs, and projects with high or uncertain cumulative effects hazard (i.e., above target and critical thresholds, or in designated hot spots)[10] are subject to enhanced assessment and review. Such review could include the OGC Advisory Committee, which would be requested to review the project as a special case, with the committee acting in an advisory capacity to regulatory reviewers. This process reflects the view that a project in an area already at 'target' or 'critical' cannot necessarily be held responsible for solving the cumulative effects problem if the problem already exists due to other projects.

What can be done beyond addressing the individual project, being a major component of the OGC's current mandate, remains the on-going responsibility of the government. Regulators could declare a change in the acceptability of further applications in these 'compromised' areas (possibly including closure to all applications until certain land and resource use objectives are met), or impose extraordinary requirements for project, joint project, and regional EMMs, such as access management or cooperative compensation programs.

In summary, the OGC's determination on the acceptability of an application would be based on the following, all reflecting elements of administrative process already in place or proposed in this SRMS:

1. relative contribution of the project to the regional threshold;
2. state of the regional threshold in consideration of contributions from all human disturbances;
3. likely trend of future land use pressures and state of environmental indicators; and
4. potential contribution of effects management options, either for that project alone or collectively through a jointly coordinated technique, in minimizing the effects.

Although Volume 2 provides specific candidate numerical thresholds, a process will be required to introduce and formalize their use. Further details are provided in that volume.

Implementation will require agreement on definitions of acceptable change, threshold values, a standard public database, a standard process to calculate indicator values using this database, and project-specific and cooperative management actions to be implemented. The existing public database will need to be enhanced and made more readily accessible. The OGC's use of the existing GIS-Oracle Access Tool (GOAT),[11] which includes map coverages for numerous themes (including certain environmental features), should likely be able to support the incorporation of the ecological thresholds approach.

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[10] The hot spot maps provided in this Volume (Section 4), although implying a threshold for each mapped feature, were not designed to correlate to the thresholds as described in Volume 2. In some cases geographic areas of concern for some features, as indicated in the hot spot maps, may possibly also occur within areas for which a target or critical threshold exists. The hot spot maps are based on a different set of criteria and serve another purpose; namely the identification of specific areas of possible concern for specific features, and are intended for use in the absence of the Volume 2 thresholds, and to supplement the scoping of possible specific areas of concern when those thresholds are implemented.

[11] Originally developed by MSRM and MWLAP.

A pilot study is recommended to better understand the ecological, economic, and social implications of threshold implementation in northeast British Columbia. Two areas with existing data and high cumulative effects hazard are proposed for consideration (see Volume 2).

4.7 Implementation

The concept of the SRMS, introduced earlier in Section 4.1.2.1 and Figure 4-1, provides a basis for practical implementation of a cumulative effects assessment and management framework. The SRMS is the name given to a CEAMF that is customized to specifically meet the needs of the OGC, and to generally meet the objectives of land and resource management in northeast BC.

The SRMS is discussed here in more detail based on the concept illustrated in Figure 4-8. The SRMS includes two specific approaches or 'tracks' that work both independently and in a coordinated fashion, along with some common components between them.

4.7.1 Dual Tracks

The dual track approach directly reflects the two foundations of the SRMS: initiatives associated with specific projects, and initiatives pursued at a regional scale not directly associated with specific projects (but typically reflecting the collective or cumulative influence of many projects).

Track One (the initiatives on the left side of Figure 4-8) is based on addressing cumulative effects at the project-specific level. It includes the ACES (Section 4.2.3 and Appendix G), project matrices (Appendix F, for oil and gas projects only), and various EMMs (discussed in Section 4.5.3).

Track Two (the initiatives on the right side of Figure 4-8) is based on regional initiatives that contribute to both improved land and resource use planning and individual project review (by providing improved information on which to test the project application). This track includes the Regional Assessment (Section 3, including regional issues, description of environmental features, and hot spots), regional studies, various regional EMMs, land and resource management objectives, and thresholds (Volume 2).

Figure 4-8. Sustainable Resource Management Strategy

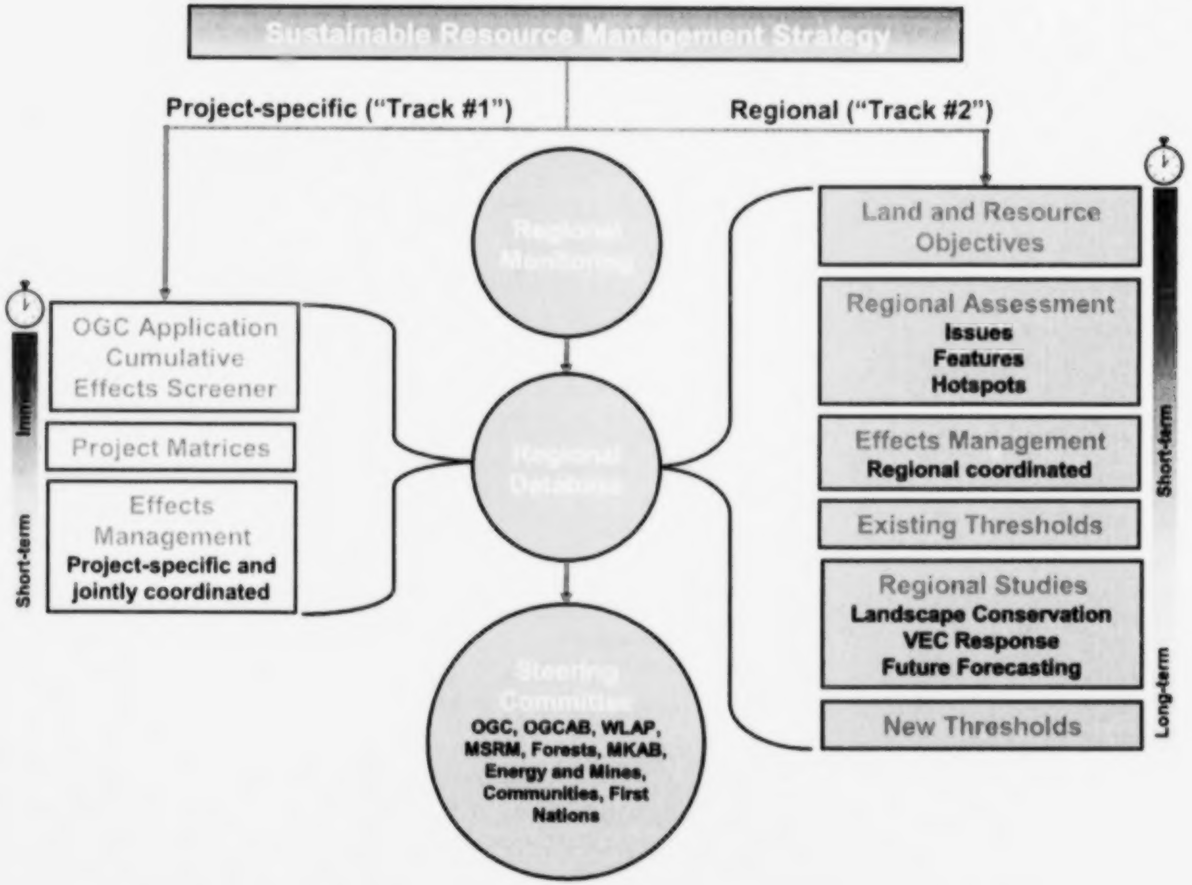
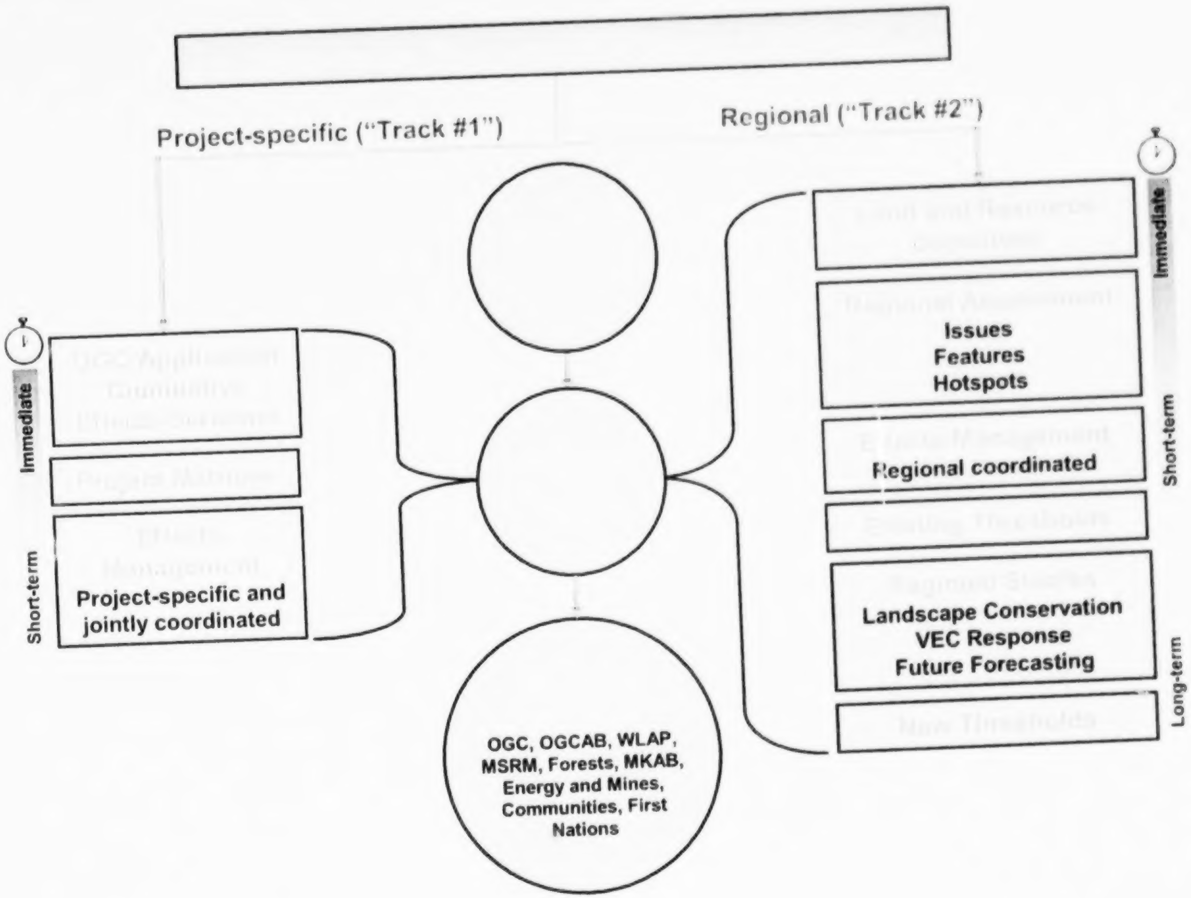


Figure 4-8. Sustainable Resource Management Strategy



Both tracks include components that are already implemented, may be immediately implemented, or may require more time before they are ready to be implemented.

The components of both tracks have been described earlier in detail. Further common elements between the two tracks — Regional Steering Committee, regional database, and regional monitoring — are described below.

4.7.2 Common Elements

4.7.2.1 Steering Committee

The purpose of the proposed SRMS Steering Committee is to guide direction of the SRMS in northeast BC. The objectives of the committee would include:

- identifying and coordinating joint regional initiatives that are consistent with and contribute to the achievement of a regional land use vision as defined through strategic level plans;
- identifying more clear and pragmatic land and resource use objectives that can be used at the operational level of the OGC and provincial ministries;
- sourcing funding for joint regional initiatives;
- forecasting future land use and environmental trends and identifying appropriate responses;
- facilitating government and industry information transfer and decision-making on land and resource use;
- identifying and prioritizing research areas aimed at developing thresholds for managing cumulative effects;
- guiding the development of regional monitoring programs (e.g., through defining data requirements, indicators), reviewing the results from such programs, and identifying appropriate project or regional actions; and
- critiquing the effectiveness of initiatives in contributing to the regional goals which they advocate.

The committee would be composed of regional stakeholders, possibly drawn from all or a combination of the following organizations: OGC; OGC Advisory Committee; Ministry of Water, Land and Air Protection; Ministry of Forests; Ministry of Sustainable Resource Management; Ministry of Energy and Mines; Muskwa-Kechika Advisory Board (MKAB); First Nations; industry; local communities; and NGOs. The roles and responsibilities of the committee has similarities to that of the MKAB, especially regarding a mandate to generally oversee the direction of a large geographic area under multiple land use pressures.

Precedents to the use of a central advisory body serving similar functions can be found in other existing initiatives (Appendix B). The NES Strategy in Alberta uses a similar body, consisting of members that will be directly affected by the outcome of the strategy. Members are to sit as individuals and not as representatives of groups or constituencies. The Northwest Territories CEAMF also includes the involvement of a steering committee. In some cases, a professional, independent facilitator oversees the meetings of the committees.

A funding arrangement for the SRMS Steering Committee could be structured similar to that already in place by the Cumulative Effects Management Association (CEMA) initiative in Alberta's Athabasca Oil Sands (Appendix B). In the CEMA example, the framework is jointly funded by industry and government, and is facilitated by a secretariat.

4.7.2.2 Regional Database

The purpose of the regional database is to provide a centralized repository of land use and environmental information that could be accessed as part of project-specific or regional cumulative effects assessment and management initiatives. Objectives to be met by the database include:

- providing OGC staff with the information they may need to review applications and better assess the acceptability of new projects. This would include information about the threshold(s) state (i.e., cautionary, target, critical) within the land management area to which the application applies, as well as the threshold tests (i.e., the degree of contribution of individual projects to the defined thresholds for this area);

- providing information to the Steering Committee and ministries with land and resource use management responsibilities that assists them in better understanding the state of land use and the environment; and

- providing proponents with information that would assist them in better characterizing the land use and environmental setting of their project, and in calculating their project's contribution to land use and/or defined thresholds.

The information contained in the regional database would be spatially referenced (i.e., in a GIS system), readily accessible, and available to the public. Information would be collected from existing databases, individual project applications, and regional effects management initiatives, especially regional monitoring programs.

Use of a regional database as a tool to facilitate management of cumulative effects has precedent in the CEMA initiative, which is working towards managing the cumulative effects of industrial activities in the Athabasca Oil Sands Region of Alberta. CEMA is using a Regional Information System (RIS) to manage the vast amounts of data being collected through its various working groups and independent research initiatives in the region.

4.7.2.3 Regional Monitoring

The purpose of regional monitoring is to collect up-to-date information on changes in environmental conditions and land use in the study area. These data are then incorporated into the regional database and made available to all parties. Objectives to be met by monitoring include:

- tracking land use features and patterns, particularly access corridors (in support of the proposed thresholds relying on road and trail features);
- tracking post-reclamation recovery of disturbed sites;
- compiling data from field surveys of ecological indicators (e.g., herd populations, watershed forest cover). The selection of such indicators should be based on the particular human impacts and ecological features within the area of concern;
- verifying the appropriate implementation of EMMs and monitoring their success; and
- identifying major natural or human caused effects (e.g., insect infestations and areas of 'boom' natural gas exploration, respectively) that may accelerate the approach of any given area to a higher threshold level (i.e., an 'early-warning' check that supplements the threshold-based indicators).

Monitoring for all of these objectives, for the practical reasons of cost and capacity, is likely not possible within the entire northeast BC study area by any one or even a combination of existing administrative bodies; therefore, customized monitoring programs, likely under partnership arrangements, must be established to meet priority areas of concern based on level and type of human activity, and on the level of concern for affected environmental features.

4.7.3 Roles and Responsibilities

The following outlines roles and responsibilities of key participants in the SRMS:

4.7.3.1 Government (Resource Managers and Planners)

Government staff that would have the most direct role in implementing the SRMS are resource managers and planners.

Working individually and jointly, their roles include:

- identifying land and resource use objectives;
- establishing criteria for land use acceptability that are consistent with land and resource use objectives;
- considering cumulative effects in their permitting and regulation of activities for which they have authority;
- providing information necessary for project proponents to determine contribution to regional thresholds (if available);
- participating in application referrals; and
- administering, co-ordinating, and supporting regional initiatives (e.g., mitigation, monitoring, planning, threshold identification, future scenario forecasting, regional environmental and land use database).

4.7.3.2 Application Reviewers

Regulators who review project applications include OCG staff as well as First Nations or government ministries to which applications may be referred by the OGC. These groups play a critical role in addressing cumulative effects issues at a project-specific level.

Their principle roles are:

- defining clear information requirements and application guidelines for project proponents;
- screening project applications;
- accessing available information;
- requesting new information and facilitating incorporation of new information into the regional database;
- applying criteria on evaluating contributing effects based on results and tests from resource planning (e.g., hot spots, thresholds);
- determining the fate of applications, using available information on project and environmental setting; and
- recommending management responses and conditions for reasonable and appropriate mitigation and monitoring, some which would need to be performed jointly.

4.7.3.3 Project Proponents

Project proponents are those who submit project applications and, by nature of their applications, conduct the first level of assessment of project-specific and regional cumulative effects.

In terms of the CEAMF, the role of project proponents are:

- calculating their contribution to regional thresholds (if available);
- preparing and submitting an application;
- responding to information requirements and requests;
- implementing conditions of project approval; and
- potentially joining and/or funding (either voluntarily or by requirement) new or on-going joint or regional effects management initiatives.

4.7.3.4 Steering Committee

The objectives and proposed structure of a SRMS Steering Committee has been described in Section 4.7.2.1.

Specifically, its roles are:

- advising government and industry on appropriate actions as they relate to cumulative effects;
- improving sharing of information and communication within government, and between government and other stakeholders;
- providing a forum for government, industry, and the public to participate in implementation of the CEAMF; and
- identifying priorities for research and regional effects management initiatives.

4.7.3.5 First Nations

There is a legal relationship between the Government of BC and proponents to ensure that activities on Crown land do not infringe on existing aboriginal rights and title unless there is proper justification; consequently, there is need for the SRMS to identify, incorporate, and consider First Nations' values and interests on the land base.

Some of the roles of First Nations are:

- participating in application review as part of referral process;
- identifying ways in which indigenous knowledge can contribute to the regional database while recognizing the sensitivity of this information and maintaining First Nations ownership;
- helping application reviewers determine how a project will affect First Nations interests and values (e.g., by identifying specific issues or hot spots); and
- identifying indicators to help measure regional effects on First Nations values, and participating in research initiatives that address these indicators.

4.7.3.6 Muskwa-Kechika Advisory Board

The Muskwa-Kechika Advisory Board (MKAB) would play a similar role in the MKMA as the SRMS Steering Committee plays for the region as a whole. They would maintain the distinctive strategic role they currently provide, and participate in initiatives that have implications for cumulative effects within the MKMA.

The roles of the MKAB include:

- participating in planning processes within the MKMA (e.g., pre-tenure planning, wildlife management plan) that serve to identify management objectives and define appropriate land uses;
- advising government and industry on appropriate actions as they relate to cumulative effects within the MKMA;
- improving sharing of information and communication among stakeholders;

- providing independent review of complex and unusual proposals within the MKMA;
- identifying priorities for research and regional effects management initiatives within the MKMA; and
- participating with the Steering Committee to ensure that the concerns of the board are expressed.

4.7.3.7 Public and Non-Government Organizations

Private citizens and member of non-government organizations can actively participate in the implementation of the SRMS.

Their roles include:

- participating in planning processes that set regional land use vision and objectives;
- identifying issues of concern, and valued ecosystem and social components;
- providing independent review of complex and unusual proposals;
- acting as a 'watchdog' as to the success of SRMS implementation; and
- participating with the Steering Committee to ensure that general public and community concerns are expressed.

4.7.4 Decision and Information Flow

Figure 4-9 illustrates how the individual parts of the SRMS, as introduced in Figure 4-8 and described above, sequentially fit together into a series of clear and consistent steps. This shows who does what, where one starts, where one ends (and with what products and results), and what it takes to get through the process. The figure, therefore, summarizes where the decisions are made and how the information flows.

This decision and information flow essentially consists of four major parts, identified by the letters A, B, C, and D in Figure 4-9, as summarized below:

- **Part A *Preparation***: This part prepares the information needed for the SRMS to begin. It includes the identification and verification of existing land and resource use objectives, and the review of available land and resource use information. Once this is completed, implementation splits between the two SRMS tracks based on whether the intended actions relate to project-specific review or regional planning and research.
- **Part B *Project-specific Review***: This part processes individual project applications through the existing OGC review process, modified by addition of the proposed ACES. Possible additional review by other regulatory bodies can be added.
- **Part C *Regional Planning***: This part implements various planning and research activities, some possibly related to the development and refinement of thresholds,

that will eventually help improve understanding of land and resource use in the region, and of the effects of such uses on valued components.

- **Part D: *Regional Monitoring***: This part, common to Parts B and C, provides the means of collecting and updating information that will eventually feed back into the process. Part D sees the process return to the earlier decision point from which either a new project application is reviewed or a new regional initiative is begun. This indefinite cyclic pattern reflects the principles of adaptive management (i.e., modify an action based on more recently obtained information and review of earlier assumptions).

Viewed in another way, the SRMS reflects initial planning (Part A), regulation by sector (Part B), and adaptive resource management (Parts C and D) to provide a complete and integrated response to assessing and managing cumulative effects both on a project and regional basis.

Table 4-3 provides some examples of typical situations in which cumulative effects concerns arise. First introduced in Section 4.1.1 as examples of cumulative effects problems, the table provides an example of a course of action constituting possible solutions based on the SRMS model. This table, therefore, serves as guidance, by way of example, on how the pieces of the SRMS may come together. Specific decision-makers or advisory bodies active in the northeast study area would pick and choose the most appropriate information and tools from the SRMS to assist them in whatever task they face, whether on a day-to-day basis for specific applications or strategically over an extended period of time.

Figure 4-9. Pulling it all Together: SRMS Decision and Information Flow

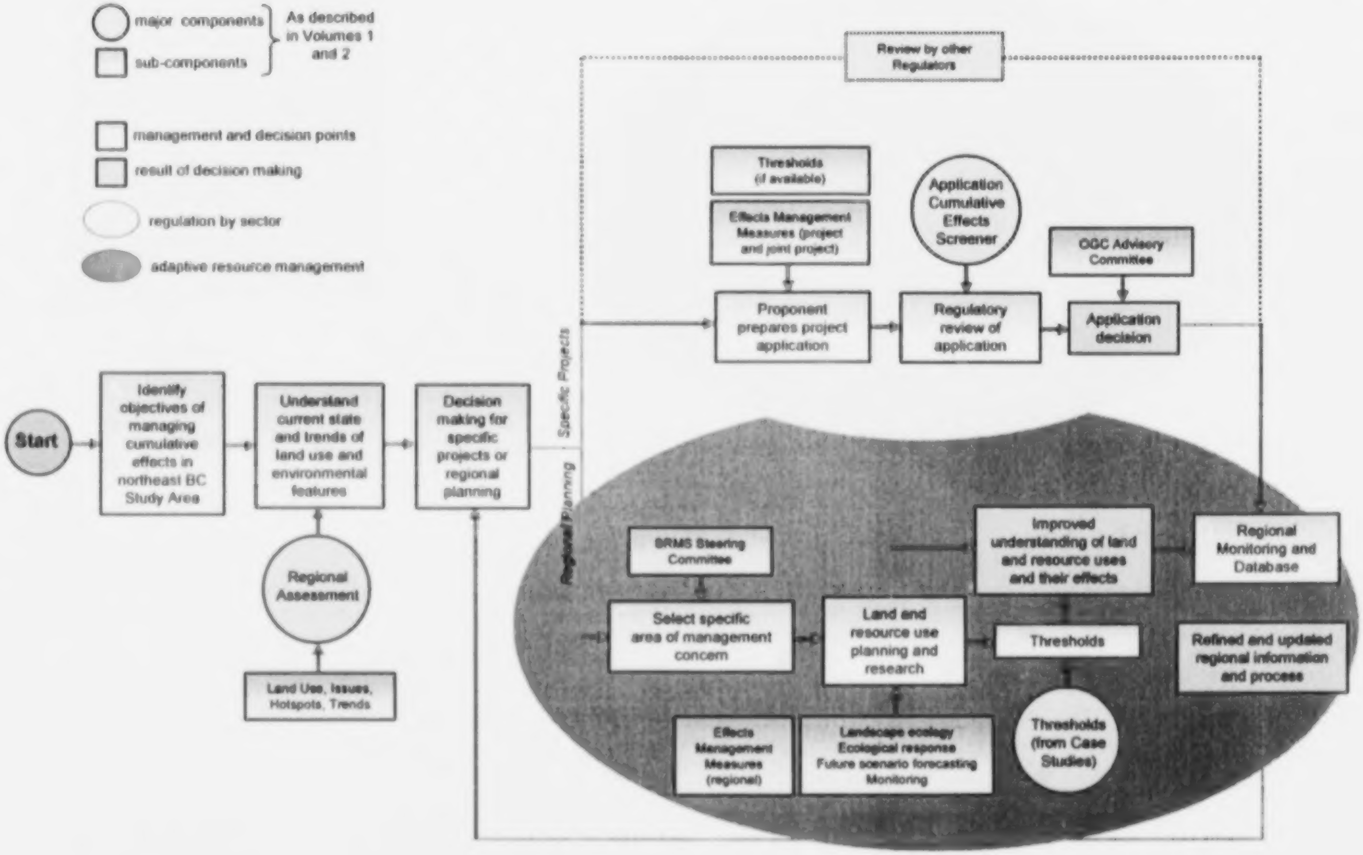
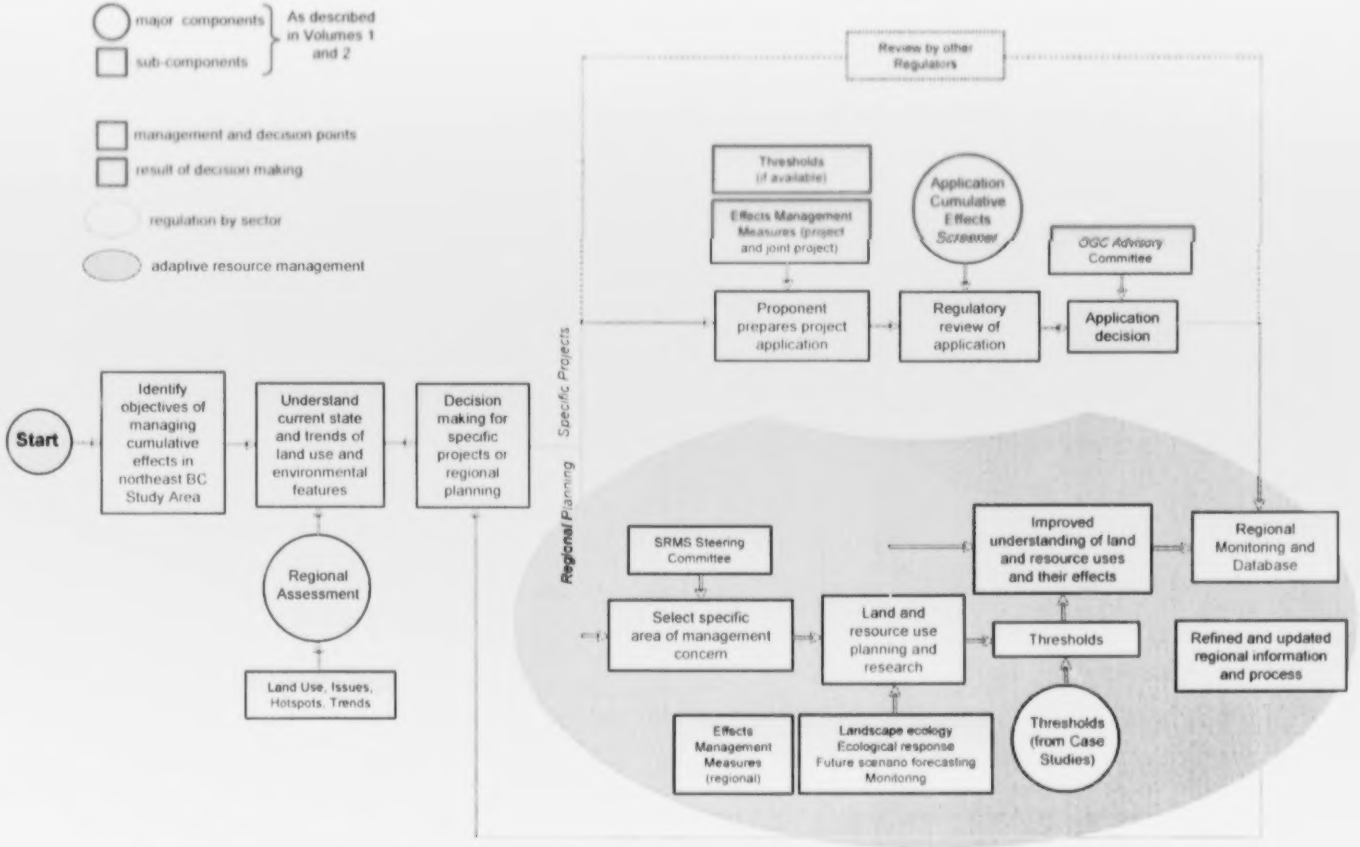

major components
sub-components
As described in Volumes 1 and 2
management and decision points
result of decision making
regulation by sector
adaptive resource management
Start
Identify objectives of managing cumulative effects in northeast BC Study Area
Understand current state and trends of land use and environmental features
Regional Assessment
Land Use, Issues, Hotspots, Trends
Decision making for specific projects or regional planning
Specific Projects
Regional Planning
Review by other Regulators
Thresholds (if available)
Effects Management Measures (project and joint project)
Proponent prepares project application
Application Cumulative Effects Screener
Regulatory review of application
OGC Advisory Committee
Application decision
SRMS Steering Committee
Select specific area of management concern
Land and resource use planning and research
Improved understanding of land and resource uses and their effects
Regional Monitoring and Database
Thresholds
Refined and updated regional information and process
Effects Management Measures (regional)
Landscape ecology
Ecological response
Future scenario forecasting
Monitoring
Thresholds (from Case Studies)

Figure 4-9. Pulling it all Together: SRMS Decision and Information Flow


major components
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Specific Projects
Regional Planning
Review by other Regulators
Thresholds (if available)
Effects Management Measures (project and joint project)
Proponent prepares project application
Application Cumulative Effects Screener
Regulatory review of application
OGC Advisory Committee
Application decision
SRMS Steering Committee
Select specific area of management concern
Land and resource use planning and research
Effects Management Measures (regional)
Landscape ecology
Ecological response
Future scenario forecasting
Monitoring
Thresholds
Thresholds (from Case Studies)
Improved understanding of land and resource uses and their effects
Regional Monitoring and Database
Refined and updated regional information and process

Table 4-3. Examples of SRMS Implementation Scenarios

Scenario	Issue of Concern	Example Solution
A proponent wishes to construct another well in a certain area (e.g., a valley, a new natural gas pool), where there are currently already a number of resource users.	Will this additional application compromise something of environmental importance?	The OGC reviews the application using ACES's routine screener. The application is approved with project-specific or regional EMMs, or forwarded to Expanded Cumulative Effects Review.
A proponent wishes to construct a resource access road in a topographically constrained area, such as a valley, that is currently inaccessible except by an ATV trail.	What are the future implications of more use once the road is built?	The OGC reviews the application using ACES and determines that cumulative effects based on known conditions are unlikely. Government bodies responsible for land and resource management in that area determine if any additional planning or EMMs should be introduced to apply to possible future activities.
An area of well-defined boundaries is already experiencing 'boom' conditions and applications for project approvals are coming in faster than due process allows time to investigate some matters of environmental concern (unless substantial delay occurs in the reviews).	What is the most effective way in such situations to not compromise on environmental responsibilities?	The OGC reviews the application using ACES. Most applications automatically default to regional EMMs. Government bodies responsible for land and resource management in that area adaptively prioritize and coordinate regional EMMs, whereby the implications of on-going development and existing thresholds are re-evaluated to ensure that government response is as effective as possible.
An area of generally understood boundaries that is currently experiencing minor human use and is expected to substantially pick up in the future in regards to resource extraction (e.g., coal bed methane, natural gas, or timber harvesting).	What can be done now to prepare for this eventuality?	Government bodies responsible for land and resource management in that area review current state of environment and land use conditions, forecast possible future changes to these conditions, and design appropriate additional planning or EMMs to apply to possible future activities.

In conclusion, the SRMS approach reflects the following:

- There is not necessarily one solution to the cumulative effects problem (as expressed in Section 4.1.1), nor one perfect solution. There are a variety of options to choose from, many described in the framework, to meet the needs of any given situation.

- Application of thresholds works in parallel with the application of effects management measures. Both contribute to addressing cumulative effects in their own way. The use of EMMs becomes particularly important when thresholds have not yet been implemented as part of regulatory review or planning.

- The proposed thresholds (Volume 2) represent a coarse scale approach that, if applied over time over large areas for any types of human disturbances, will contribute to collectively minimizing cumulative effects. Application of these thresholds will not necessarily address immediate and specific local issues of concern. For example, in the second scenario involving the road in the valley (Table 4-3), there does not yet exist (anywhere) an approach that, at such relatively small spatial scales and for a wide variety of possible environmental effects, will confidently determine how much activity in the valley is too much.

- Some approaches can be exercised by individual project proponents and the OGC based on either the on-going implementation of effective EMMs or the control of allowable activities through the use of thresholds. This approach does place considerable reliance on the effectiveness of the EMMs; as such, adaptively monitoring and modifying EMMs is critical to ensure they will continue to contribute to eliminating or reducing cumulative effects.

- Some approaches can be exercised by government, and influenced by advisory bodies, based on regional planning, forecasting, and research.

CHAPTER 5: SUMMARY AND RECOMMENDATIONS

CUMULATIVE [illegible] MANAGEMENT FRAMEWORK (CEAMF) STUDY

5 Summary and Recommendations

5.1 Summary of Key Framework Components

The purpose of this report is to describe a framework to assess and manage cumulative effects in northeast BC. A regional Cumulative Effects Assessment and Management Framework (CEAMF) is an administrative structure that combines various initiatives that assist decision-makers in assessing and managing the effects of human use on the land. This framework was developed in response to concerns in the region about the possibility of worsening environmental effects due to multiple land and resource use activities. Specific concerns exist about the potential contributions of oil and gas projects to these effects.

Previous sections of this report have described the key components of the CEAMF; namely:

1. **Regional assessment:** The regional assessment characterizes the state of the land and resource use in the study area. It also describes environmental features (air quality, soils and terrain, aquatic resources, vegetation, and wildlife) according to their respective issues, effects, valued components, and specific areas of possible concern (referred to as hot spots). The regional assessment provides, at a coarse scale over a large geographic area, information of use to both project-specific reviewers and regional planners.

2. **Regional Planning and Research Studies:** Regional planning and research studies are described, providing various initiatives that improve and add to existing information that is useful and necessary to decision-makers. Regional planning and research studies that would likely have the greatest contribution to the development of thresholds are applied landscape ecology, ecological response studies, future scenario forecasting, and effects monitoring.

3. **Effects Management:** Effects management includes any measures that can minimize or eliminate effects from human disturbances. Effects Management Measures (EMM) may either be the responsibility of a single project proponent, of multiple project proponents, or of government. As such, these measures are either project-specific or regional in nature. Twenty-nine EMMs are described, recognizing those already being implemented or considered in northeast BC and elsewhere, as well as new and innovative approaches.

4. **Project Assessment Matrices:** The project assessment matrices provide generic and specific information that is useful in the review of individual oil and gas project applications. This information covers seven disciplines that are commonly examined in EIAs: air quality; soils and terrain; aquatic ecosystems; vegetation; wildlife; land and resource use; and First Nations. The information provided in the matrices is based on the five conventional steps in project assessment, including scoping, analysis, mitigation, significance evaluation, and follow-up.

5. **Project Screener:** The project screener, referred to as the Application Cumulative Effects Screener (ACES), is a step-by-step process for OGC staff to follow when reviewing project applications for possible cumulative effects issues. The process has two options: one is a simple series of questions that can be answered readily with available information; and the other is based on thresholds that can be used when they become available. An expanded review process is also described for situations warranting more detailed review of an application as a result of certain environmental concerns.

6. **Thresholds:** Thresholds are measures of limits of acceptable change. Four types of thresholds are proposed based on access density in broad landscapes, access density within watersheds, core habitat security, and species-specific thresholds. In the framework, contribution to the threshold by each project is compared to three levels of thresholds (cautionary, target, and critical). The thresholds are introduced and summarized in this report, and are fully detailed in Volume 2.

7. **Monitoring:** Monitoring is the ongoing determination of environmental conditions, the verification of predicted effects, and the verification of the effectiveness of applied effects management measures. Monitoring is a critical component of the CEAMF in that it can help measure the effectiveness of EMMs, and can help reduce cumulative effects.

8. **Sustainable Resource Management Strategy**: The Sustainable Resource Management Strategy (SRMS) is a version of a CEAMF (which is a generic term) that is customized for northeast BC. While focused on addressing oil and gas projects within this discrete region, it can be adapted to address the cumulative effects of any type of human activity, and adapted for implementation elsewhere in BC. The SRMS essentially ties together all the individual components (i.e., points 1 to 7 above) into one sequential series of steps. It includes three principal parts: initial planning; regulation by sector; and adaptive resource management. Fundamental to the SRMS is the concept of a dual-track approach, whereby cumulative effects are addressed both by examination of individual project applications and on a regional and jointly supported basis.

The proposed approach to assessing and managing cumulative effects is based on many tools or options that would each contribute in their own way, or would work together, collectively. Each tool or option provides an opportunity to address cumulative effects issues, at earlier or later points in time, depending on available resources and acceptance at whatever government, industry, and public level of participation is appropriate.

5.2 Contributions of the SRMS to Science and Decision-making

Although other regions have attempted to develop and implement frameworks for addressing cumulative effects (see Appendix B), the proposed SRMS for northeast BC makes a significant contribution to science and decision-making, and is unique in comparison to many other frameworks in its emphasis on immediate and practical implementation.

Specifically, the SRMS contributes to science and decision-making as described below.

- It can be immediately and practically applied as it builds on existing tools and requires limited changes to the current administrative and management structures in place for the region (the only change being the addition of the proposed SRMS Steering Committee).
- It recognizes and is consistent with both local and strategic level planning for the region. As such, the implementation of the framework does not require that land use objectives be re-visited in the short term although it recommends that such objectives occasionally be reaffirmed in light of new information.
- It builds on and supports scientific research and provides a mechanism (in the form of the regional, publicly-accessible database) that can be used to continually update the state of knowledge for the region. The regional database is a tool to identify geographic areas of concern (i.e., hot spots), prioritize areas for future research, and adapt land management plans and strategies in light of new information and data.
- While focused on the environmental effects of oil and gas activities, the concepts presented in the framework are readily adaptable for use by other land management agencies and for use in the assessment and management of social, cultural, recreational and economic effects.
- It provides realistic options for assessing, managing, and mitigating cumulative effects resulting from oil and gas activities, at both the local and regional scale, based on knowledge of what is appropriate to the region and what has been proven successful elsewhere.
- It breaks new ground in its identification of scientifically-based indicators and thresholds, which are customized for use in the region to which they would be applied, and which are implementable at a pilot scale in the short term (in conjunction with the recommended project screener). The proposed thresholds represent a coarse scale approach that, if applied over time over large areas for any type of human disturbances, would collectively minimize cumulative effects.
- It recommends a workable and non-onerous approach to incorporating cumulative effects into the day-to-day application review procedures currently in place by the OGC, while requiring only minimal changes to those procedures for the majority of application reviews. The project screener (ACES) provides the OGC with a formalized approach to assessing and managing cumulative effects and meeting due diligence requirements.
- It relies not on one management agency to solve the problems of cumulative effects but rather provides an 'umbrella' under which all cumulative effects management decisions could be made, by any agency or organisation, at any time. The introduction of a regional steering committee to specifically address cumulative effects issues in Northeast BC is a unique concept for the region.
- In generally, it provides reference points, guidance and options which support decision-making, which are adaptable to a variety of situations, and which are linked to other planning and management processes at the local, sub-regional, and regional scales.

5.3 Recommendations

The principal recommendation of this report is to adopt the Sustainable Resource Management Strategy (SRMS) as a means of practically implementing a region-wide CEAMF. The eight recommendations that follow provide specific direction for implementing the critical components of the SRMS. Given the integrated and adaptive nature of the SRMS, each recommendation is linked to the others. Further, each recommendation has one or more 'ongoing' components making it difficult to classify the recommendations according to short, medium or long timeframes. That said; many of the recommendations could be implemented immediately, using existing information and data, while others could be phased in over time as resources and pertinent information become available.

It is expected that the OGC and MKAB, in consultation with other ministries and stakeholders, and in consideration of available resources and current priorities, would determine which of the recommendations they have the capacity to immediately implement, and which would be attended to at some point in the future. Notwithstanding this expectation, it is the first four recommendations that would provide the greatest overall contribution to the framework and would effectively 'set the stage' for the implementation of the remaining recommendations. The first recommendation is overarching, while the other three specifically address the steering committee, data management, and project screening components of the SRMS.

1. Adopt a 'dual-track' approach so that cumulative effects can be addressed at two levels: project-specific and regional

Cumulative effects should be tackled both by addressing individual projects, and by undertaking regional initiatives (i.e., those that are not directly tied by regulatory mechanisms to any one specific project). This is referred to as a 'dual-track' approach. Components of the SRMS that are applicable to Track 1 (project-specific) are project-specific assessments, application screening, and project effects management measures. Each of these can be implemented immediately and adapted on an ongoing basis. Components of the SRMS that are applicable to Track 2 (regional) are land and resource management objectives, regional-scale assessment of cumulative effects issues and hot spots, regional studies, thresholds, and effects management measures. Each of the components can be implemented as time and resources permit.

2. Form a central SRMS Steering Committee to advise on regional initiatives

Solution of the cumulative effects problem is ultimately a shared responsibility among regional stakeholders. Further, co-ordination of resource use decisions within government, and the availability of information to support decision-making, are required before any meaningful solution to the cumulative effects problem becomes apparent. The dual mandate of protecting the natural environment and accessing and extracting natural resources can only be accomplished through collaboration and the support of new initiatives. Recognizing these realities, some components of the SRMS, and, in fact, many of the critical aspects of the SRMS (particularly in Track 2: Regional) can only be exercised collaboratively. Thus the formation of a central SRMS Steering Committee is recommended.

The Steering Committee would play a key role in advising government and industry on appropriate actions as they relate to cumulative effects, improving the sharing and communication of information, providing a forum for broad participation in implementation of the SRMS, and identifying priorities for research and regional effects management initiatives. The committee would be composed of regional stakeholders, possibly drawn from government agencies (local, regional, provincial, and federal), the Muskwa Kechika Advisory Board (MKAB), the OGC Advisory Board, First Nations, industry, local communities, and NGOs. The first tasks relating to this recommendation are the selection of participants and the development of Terms of Reference based upon the provided preliminary list of roles and responsibilities.

3. Establish and maintain a centrally located and publicly-accessible regional database of information that builds on the information collected and utilized as part of the Regional Assessment component of the framework

The purpose of the regional database is to provide a centralized repository of land use and environmental information that could be accessed as part of project-specific or regional cumulative effects assessment and management initiatives. The information contained in the regional database would be spatially referenced (i.e., in a GIS system), readily accessible, and available to the public. Information would be collected from existing databases, individual project applications, and regional effects management initiatives (especially regional monitoring programs), and would require regular updating. The results of analyses conducted using these data (e.g., the creation of hot spot maps) should also be made readily available.

4. Amend the current OGC application review process to incorporate a screening for cumulative effects

There is an opportunity within the existing OGC review process, at the screener stage, to incorporate consideration of cumulative effects for individual project applications that is not onerous, and would not threaten the timely and efficient review process, assuming that certain information sources are available. The recommended screening approach is based on a clear series of steps; however, to implement the screener, two changes to the existing OGC review process are required:

- if thresholds are implemented, then applicants should provide the OGC with a calculation of their project's contribution to the regional threshold (as explained in more detail in Volume 2); and
- for OGC staff (i.e., resource officers and managers), additional time should be allocated to complete a series of checks and selections using various information sources, including maps and look-up tables.

5. Continue the process begun as part of Volume 2 of this work relating to the identification and implementation of appropriate cumulative effects indicators and thresholds for northeast BC

Once approved within an implementation process that is practical and not onerous, use of a wide suite of context-specific thresholds (i.e., correlated to specific areas and environmental features of concern), whether as part of project-specific review or regional land use planning, offer the most effective tool to address cumulative effects. However, their practical implementation will take time given the need to develop capacity to support them and to obtain agreement by stakeholders. To implement thresholds broadly throughout northeast BC, initiation of a pilot program is recommended to demonstrate practical application of thresholds within a regulatory review and provincial planning process. Following a successful pilot, thresholds would be incorporated within the OGC's and other review processes. Detailed recommendations relating to a thresholds implementation strategy, and expected outcomes of such a strategy, are discussed in Volume 2.

6. Encourage research projects on cumulative effects issues in the region, and incorporate the results back into the framework

An important component of any CEAMF is research, which provides information necessary for understanding impact mechanisms and interactions, defining thresholds, and employing best management practices and adaptive management principles. Research themes that will, over time, most directly advance the assessment and management of cumulative effects (e.g., development of thresholds) include landscape ecology, ecological response studies, future scenario forecasting, and monitoring. The SRMS Steering Committee would play a key role in identifying research priorities, and in co-ordinating the incorporation of research results back into the regional database. Mechanisms to fund such research are already in place in the form of, for example, the OGC's Environmental Fund (since renamed the Science & Community Environmental Knowledge Fund), and the Muskwa-Kechika Trust Fund.

7. Make information on appropriate Effects Management Measures (EMM) available to proponents and land and resource planners, coordinate joint and regional EMMs, and monitor the effectiveness of EMMs in reducing cumulative effects

The management of project effects, whether implemented for individual projects at a time or jointly for various projects, provides immediate to near-term opportunities to eliminate or substantially reduce environmental effects and the pace at which those effects occur. There already are many management techniques being implemented in northeast BC. Some of these, and others, are gaining wide acceptance and implementation in other jurisdictions (such as Alberta), and are all readily adaptable to BC. Related to government responsibility is the need to involve more than one government department, ministry, or agency during project reviews or planning if cumulative effects are to be addressed. The participation of other project proponents would further broaden the scope of effects management, and therefore, increase the success of such measures. Also, other proponents should be involved with overlapping interests, including oil and gas operators and those from other sectors (such as forestry).

In the absence of thresholds, the SRMS places considerable reliance on the effectiveness of the EMMs; as such, adaptively monitoring and modifying EMMs is critical to ensure that they will continue to contribute to eliminating or reducing cumulative effects. In addition to monitoring undertaken by proponents, priority for research funding should be given to research projects that monitor and assess the effectiveness of various project-specific and region EMMs.

8. Implement an adaptive management approach that monitors key indicators and collects new information to feed back into the framework and database

The purpose of regional monitoring is to collect up-to-date information on changes in environmental conditions and land use in the study area. These data are then incorporated into the regional database and made available to all parties. With the incorporation of monitoring and adaptive on-going evaluation of framework objectives and procedures, the framework can continually evolve to meet the mandate of government and the interests of northern BC communities and resource users.

CHAPTER 6: REFERENCES

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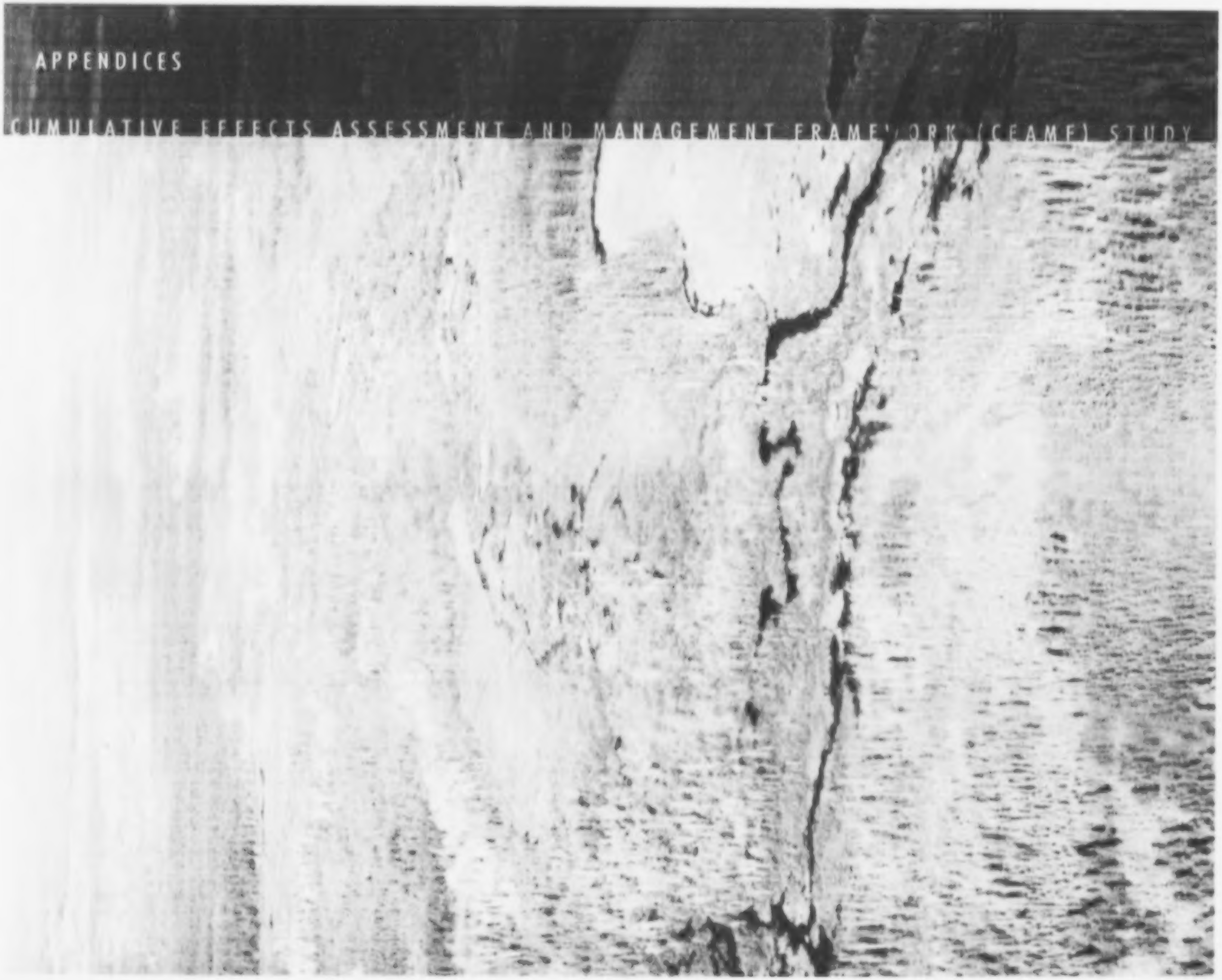
APPENDICES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



Appendix A: Project Terms of Reference

The Terms of Reference for the project have been extracted from three integrated proposals submitted to the BC Oil and Gas Commission in April 2000. Some of the terminology used in the proposal documents and subsequent project Terms of Reference may differ from terminology used in the report.

COMPONENT 1: Development of a Practical Framework for Cumulative Effects Assessment and Management for Northeast British Columbia

Project Summary

AXYS Environmental Consulting Ltd., Diversified Environmental Services and Salmo Consulting Inc. are proposing to conduct three separate but integrated studies which, in combination, will provide an over-arching strategy and approach for identifying, scoping, assessing, and managing cumulative effects in northeast BC (these components will be referred to collectively as cumulative effects assessment and management (CEAM)). All three components will contribute towards the development of a decision-support framework for aiding the BC Oil and Gas Commission (OGC) in ensuring that cumulative effects are consistently and efficiently addressed and managed as part of their on-going project approval process. The three proposed components are:

- CEAM Framework: development of an overall approach, specific to this region, for conducting project-specific and regional cumulative effects assessments (CEA);
- CEAM Case Studies: detailed assessment of cumulative effects in two representative areas in northeast BC; and
- CEAM Project Screener: development and testing of an application screening process to assist the OGC in making decisions on project applications.

The CEAM Framework will recommend approaches for scoping CEAs (e.g., identification of important regional issues, selection of indicators for ecosystem and socio-economic effects), analytical approaches and tools for CEAs, approaches for mitigation and management, determination of impact significance (including thresholds), and follow-up and monitoring requirements. A variety of existing data sources will be used to develop a spatial overview of existing cumulative effects in the region (i.e., a regional database) so that potential areas of concerns (hot spots) can be identified and significant data gaps noted. These products can eventually be used by the OGC and industry as:

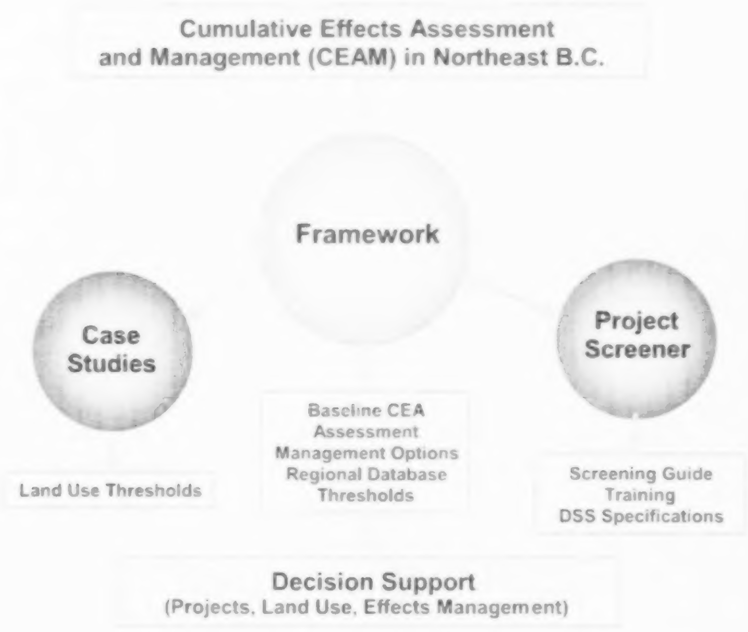
- a means to flag regional hot spots and areas requiring remediation and management;
- a preliminary planning tool to aid in review of future applications and management initiatives;
- a baseline for future assessments;
- a guide to proponents on how the CEAM Framework can be applied in an assessment;

- a practical application for incorporating results from other research; and
- a means to identify important data gaps and set priorities for follow-up and monitoring.

Background and Approach

Under the cumulative effects research envelope of the OGC Environment Fund, AXYS Environmental Consulting Ltd., Diversified Environmental Services and Salmo Consulting Inc. are proposing to conduct three separate but integrated studies which, in combination, will provide an over-arching strategy and approach for identifying, scoping, assessing, and managing cumulative effects in northeast BC (these components will be referred to collectively as cumulative effects assessment and management (CEAM)). All components will contribute towards the development of a decision-support framework for aiding the OGC in ensuring that cumulative effects are consistently and efficiently addressed and managed as part of their on-going project approval process. The three components will build from the results of existing and past initiatives such as Land and Resource Management Plans (LRMP), Forest Renewal BC policies and planning, landscape unit and pre-tenure planning, and ongoing work by the OGC. The three proposed components are (Figure A-1):

Figure A-1. Relationship Between Proposed Cumulative Effects Assessment and Management Components



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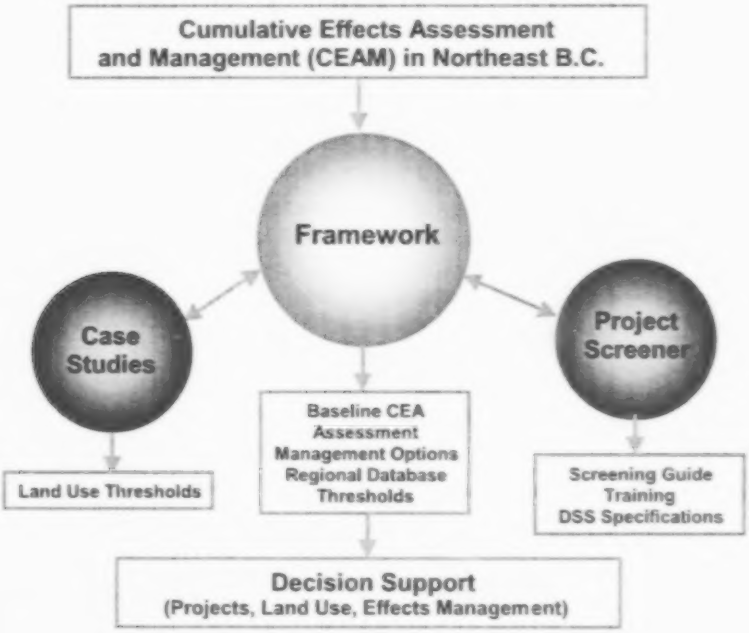
Under the cumulative effects research envelope of the OGC Environment Fund, AXYS Environmental Consulting Ltd., Diversified Environmental Services and Salmo Consulting Inc. are proposing to conduct three separate but integrated studies which, in combination, will provide an over-arching strategy and approach for identifying, scoping, assessing, and managing cumulative effects in northeast BC (these components will be referred to collectively as cumulative effects assessment and management (CEAM)). All components will contribute towards the development of a decision-support framework for aiding the OGC in ensuring that cumulative effects are consistently and efficiently addressed and managed as part of their on-going project approval process. The three components will build from the results of existing and past initiatives such as Land and Resource Management Plans (LRMP), Forest Renewal BC policies and planning, landscape unit and pre-tenure planning, and ongoing work by the OGC. The three proposed components are (Figure A-1):

Figure A-1. Relationship Between Proposed Cumulative Effects Assessment and Management Components



1. **CEAM Framework**: The framework involves the development of an overall approach, specific to the northeast, for conducting project-specific and regional cumulative effects assessments (CEA). The framework will recommend approaches for scoping of CEAs (e.g., identification of important regional issues, selection of indicators for ecosystem and socio-economic effects, setting of spatial and temporal boundaries, and identification of projects and human actions to be considered in a CEA), analytical approaches and tools for CEA, approaches for mitigation and management, determination of impact significance (including thresholds), and requirements for follow-up and monitoring. As part of the framework, a variety of existing data sources will be used to develop a spatial overview of existing cumulative effects in the region (i.e., a regional database) so that potential areas of concerns (e.g., hot spots) can be identified. Important data gaps will also be identified.

2. **CEAM Case Studies**: The case studies provide a detailed assessment of cumulative effects in two representative areas in northeast BC to demonstrate how the CEAM Framework can be used in a real context. The case studies will provide several detailed 'windows' for looking at cumulative effects in the region, and will be useful in testing and developing approaches for assessing cumulative effects, addressing impact significance, and identifying important data needs. The end product of this component will be a detailed CEA for each study area. Deliverables will include a spatially explicit database on existing biophysical and land use attributes for the study areas, the development and use of tools and indices for assessing cumulative effects appropriate to each study area, a review of existing information on thresholds for cumulative effects, recommendations to the OGC on use of these tools and thresholds, and the identification of important needs for data, analytical tools, and thresholds. Information from the case studies will be used to modify and refine the CEAM Framework.

3. **Project Screener**: The Project Screener aids staff in rapidly assessing applications for a wide range of activities and cumulative environmental effects. The screener would not reduce the responsibility and authority of the agency, but rather would provide a systematic and consistent method to assist decision makers, as well as an audit trail for documenting these decisions. This component of the proposal would entail the development and testing of an application screening process to assist the OGC in making decisions on petroleum exploration, development and production proposals, and the management of cumulative effects. This initiative would also include recommendations on establishing, managing and updating regional databases, and allocating funds for a training workshop for OGC staff. This process will reflect the CEAM Framework and will also incorporate findings of the Case Studies.

In combination, the three proposed projects will offer opportunities to immediately incorporate results from other OGC-funded research under the air emission, cumulative effects, and ecological integrity envelopes. For example, information from the ecological integrity projects could be used to better understand impact mechanisms and interactions, define thresholds for key resource groups, and identify and employ best management practices. Data derived from other research programs, such as the Muskwa-Kechika Trust and UNBC initiatives, could also easily be incorporated. We suggest that the CEAM Framework, Case Studies, and Project Screener projects be used to ensure that information from the other research projects will be of immediate and practical use by the OGC and other government agencies. The CEAM Framework could be used to encourage researchers to provide data that can be used to define impact thresholds or to better describe how cumulative effects are occurring. Similarly, developers of cumulative effects models could be encouraged to use standard spatial databases (e.g., TEM data), temporal scoping, and action inclusion lists, and to provide useful outputs to the OGC and industry.

We recognize that this is an ambitious and complex task. It is not our intent to subsume or intrude upon the authority or responsibilities of the OGC. Rather, we hope that together these three initiatives will assist the OGC in effectively addressing cumulative effects and managing the activities of the oil and gas industry in an environmentally sustainable manner. To be most effective, our team will work closely with the OGC in developing and applying the Framework, formulating input and output guidelines with other researchers, integrating industry needs, and creating the decision support system. Interactions with front-line staff in the OGC will be critical in ensuring that the approaches, processes, tools, and outputs from these initiatives are of maximum value. We believe these tools will also assist the oil and gas industry in better understanding, addressing, and managing cumulative effects, and will potentially encourage other industry users (e.g., forestry) and regional stakeholders to work with the OCG and the oil and gas industry to manage cumulative effects.

Objectives

Objectives of the project will be to:

- develop a CEAM Framework that will serve as a guide to the OGC and industry for assessing and managing cumulative effects;
- refine the CEAM Framework through workshops with the OGC, industry, and other stakeholders;
- update the draft CEAM Framework using information from the Case Studies (Component 2) and other Environment Fund research;
- complete an overview assessment of cumulative effects in northeast BC using the CEAM Framework to serve as a baseline for future assessments, as well as a demonstration of how the Framework can be used in a real application; and
- provide technical and process information to assist the development of the Project Screener (Component 3).

The end products of the CEAM Framework project will be a report and guide. The report will summarize the technical elements of the Framework (as described above), as well as the key decisions and input from the workshops. The guide will be a simpler description of the elements of the Framework and will be prepared primarily for distribution to industry proponents to assist them in ensuring that they adequately address cumulative effects issues and, most importantly, implement measures to minimize project-specific and regional cumulative effects.

Deliverables

Deliverables for the regional assessment will include:

- a 1:250,000 scale database that summarizes existing levels of human activities and infrastructure, and the status of biophysical resources, including sensitive areas;
- assessment and reporting on existing cumulative effects in the region; and
- recommendations on on-going management and upgrading of the database.

COMPONENT 2: Cumulative Effects Case Studies For Northeast British Columbia

Project Summary

Salmo Consulting Inc., Diversified Environmental Services, and AXYS Environmental Consulting Ltd. propose to complete Cumulative Effects Case Studies for one or two areas where oil and gas exploration and production have occurred under different biophysical and land management conditions. Resource Management Zones (RMZs) identified in approved Land and Resource Management Plans (LRMP) will be used as the basis for the case study areas to allow results to be applied to other areas of northeast British Columbia. Government, industry, and public stakeholders will be consulted to identify case history areas; however, one area in each of the Fort St. John and Dawson Creek Forest Districts have been proposed.

This project links with two other proposals by the same project team, namely, "Development of a Practical Framework for Cumulative Effects Assessment and Management (CEAM) for Northeast British Columbia", and the "Cumulative Effects Project Screener", both submitted under separate cover.

The case studies will help test and develop approaches for assessing cumulative effects, determining impact significance, and identifying important data needs. A Geographic Information System (GIS) model will be constructed for each finalized study area, and will include data on topography, hydrology, linear features, facilities, cleared areas, stream habitat, biogeoclimatic units, wildlife capability, merchantable timber values, rare species potential, human use, and management boundaries. Readily available digital data sources will be used and will be supplemented by interviews with knowledgeable local specialists.

Information on disturbance patterns and biophysical resource availability, abundance, distribution, and trends will be generated for one or more points in time for each study area. This work will incorporate preliminary information generated for this region, a review of available files at OGC, Ministry of Environment, Lands and Parks, and Ministry of Forests (MOF) offices, and interviews with knowledgeable individuals. Hunter and trapper harvest data and other pertinent reports will also be obtained to document historical trends in harvest and inferred abundance.

A literature review and interviews will be initiated to document recent developments and applicability of all cumulative effects models, indices, and criteria that are applicable to this area. These models and thresholds will then be tested using data from the GIS database and historical review. Important needs for data, analytical tools, and thresholds will be identified. A report for each case study area will include historical land use and disturbance trajectories; trends in abundance of biophysical resources; an annotated bibliography of potential cumulative effects models, indices, and criteria; and recommendations for future applications and data management.

Objectives and Deliverables

The objectives of the Cumulative Effects Case Studies component will be to:

- apply the approaches and methodology of the CEAM Framework (Component 1, submitted under separate cover) using detailed data from the region;

- summarize literature on cumulative effects indices and thresholds applicable to northeast BC;
- confirm suitability of these indices for OGC project screening in northeast BC;
- create a spatially-explicit Geographic Information System (GIS) model that documents existing development and biophysical features in selected study areas;
- relate biophysical resource availability, abundance, and distribution to land use and disturbance patterns, and document trends and apparent thresholds;
- assess the utility of existing data for use in cumulative effects models and assessments; and
- confirm or identify key research and monitoring issues for cumulative effects assessment and management.

The following deliverables will be provided:

- GIS electronic files for each case study area; and
- a report for each case study area that includes historical land use and disturbance trajectories; trends in abundance of biophysical resources; an annotated bibliography of potential cumulative effects models, indices, and criteria; and recommendations for future applications and data management.

COMPONENT 3: Cumulative Effects Screener

Project Summary

The proposed project involves the development of a formal process to assist decision makers in making their decisions, drawing together various types of information, and recording that information. Elements of the proposed screener include forms for the collection of information, the identification and use of various data sources (including a regional database), referrals (e.g., First Nations, MELP), the determination of effects and their significance, clear guidance to proponents on information requirements, and clear guidance to reviewers to assist them in making the "public interest" test.

This project links with two other proposals by the same project team, namely, the "Cumulative Effects Assessment and Management (CEAM) Framework", and the "CEAM Case Studies", both submitted under separate covers.

The end product of the Project Screener will be a process by which cumulative environmental effects can be consistently assessed and documented as part of the OGC's application reviews. Currently, cumulative effects are not explicitly addressed within applications, nor do OGC reviewers (e.g., Resource Officers) necessarily have available the information they require. The screener will provide them with the tools to make such considerations and to document their justification for such decisions. As more applications are reviewed, a considerable and growing amount of information can be accessed to assist reviewers.

In recognition of the now more than 1000 applications processed annually by the OGC, and the review period target of 12 working days, the proposed screener must be simple to use, fit into the existing application review process, and be clear on what constitutes cumulative effects of concern and how to arrive at such conclusions. The proposed project will make use of similar work conducted for the Department of Indian Affairs and Northern Development (DIAND) (AXYS 1997) as a basis from which a screener may be customized for the OGC's needs. This process, the only known one in Canada, assists DIAND Level 1 screeners under CEAA in identifying possible cumulative effects for permit and license applications for roads, mines, forestry operations, industrial facilities, and other types of projects.

In recognition of the need for the OGC to rapidly build its internal capability to meet increasing workloads and rising expectations for environmental review, the proposed project is designed in two phases. The first phase can be implemented with existing resources, making use of the already considerable body of available knowledge and information on land use (e.g., conformity to LRMPs). Phase 2 would build on the first phase through the design and implementation of computer-based tools, and the incorporation of information from a regional database that would be developed as part of the CEAM Framework and Case Studies. Finally, a training program would be designed and delivered to ensure that OGC staff understand the basic concepts of cumulative effects and how to effectively implement the proposed modifications to their application review process.

Objectives and Deliverables

The purpose of the Project Screener is to incorporate the consideration of cumulative environmental effects into the OGC's application reviews, and to provide an efficient and effective means of documenting the consideration of these effects in project approvals.

The objective of the program is to customize a screener for the practical day-to-day use by OGC Resource Officers so that it is simple to use, and will maintain the existing review period targets (i.e., 12 working days). Development of the screener would be phased, starting with optimizing the use of existing information and OGC resources, and progressing with the gradual incorporation of broader information sources and more sophisticated computer-based decision-making tools.

The deliverables of the proposal include:

- details for an overall phased plan to implement a screener for incorporating cumulative effects into the OGC's review of project applications;
- a detailed description of Phase 1 (Basic Screening), an immediately implementable system for OGC Resource Officers, including forms and checklists;
- a summary description of Phase 2 (Advanced Screening), including the proposed design and implementation process for an Automated Cumulative Effects Screener (see below);
- recommendations for any expanded or new information requirements from proponents; and
- delivery of a training workshop for OGC staff on cumulative effects assessment.

The attributes of the evolving screener would include:

- a process that clearly guides reviewers step-by-step;
- forms, checklists, and guidelines;
- eventual automation of a forms-based approach (see Phase 2: Advanced Screening Process);

- incorporation of information from existing data sources and referrals, eventually accessing information from a central spatial database (i.e., Geographic Information System or GIS);
- pre-defined conditions for "bump-up" to a higher level of review involving other regulatory bodies (e.g., BCEAO, NEB, DFO);
- an audit trail that records and tracks information and the conclusions that led to a decision; and
- an effects management options checklist based on the type of project and major effects.

Appendix B: Cumulative Effects Frameworks in Other Areas

The following summarizes the three best current examples of Cumulative Effects Assessment and Management Frameworks (CEAMF) in Canada. All are in western or northern Canada. They are either fully implemented (Athabasca Oil Sands) or still under development (NWT CEAMF, Northern East Slopes).

Athabasca Oil Sands Cumulative Effects Management Association

The Cumulative Effects Management Association (CEMA) is the independent organizational body responsible for facilitating the delivery of a CEAMF for the Athabasca Oil Sands in northeast Alberta. The Association, jointly funded by industry through a cost sharing agreement, was a response to the Alberta government's Regional Sustainable Development Strategy in 1999, in which a regionally coordinated approach to assessment, monitoring, research, and management was advocated as the most appropriate approach to address concerns of effects due to the many existing and proposed oil sands projects in the region.

Initiatives within CEMA are largely directed and implemented by five working groups, namely, sustainable ecosystems (including three subgroups: wildlife and fish, landscape and biodiversity, and cultural and historical resources), trace metals and air contaminants, NO_x/SO_x management, water, and reclamation.

Although most of the effort to date has focused on monitoring and baseline data collection and mapping, regional thresholds are being developed and will be implemented based on a three-tiered system (i.e., cautionary, target, and critical thresholds). A threshold already exists for Potential Acid Input, to be followed by thresholds for air quality and ecological effects due to airborne transport of contaminants.

Additional information can be found at the following URL:

http://www.cemaonline.ca

Northwest Territories CEAMF

The Northwest Territories (NWT) CEAMF was initiated in late 1999 as a condition to the approval, under the *Canadian Environmental Assessment Act* (CEAA), of the Diavik diamond mine, and in recognition of further regional potential environmental effects, especially those due to future exploration and development of mineral and diamond resources. A steering committee was formed in early 2000, which has established priorities and overseen the focusing of the framework's design. A secretariat from the Department of Indian Affairs and Northern Development (DIAND) in Yellowknife provides administrative support. The majority of funding comes though Diavik, DIAND, and the federal Department of the Environment (DOE).

The geographic area included covers all of the NWT south of the Inuvialuit Settlement Region, thus representing a large portion of the Mackenzie River Basin.

A preliminary framework was developed by late 2001; however, progress has been delayed due to funding issues and the inherent challenges of establishing direction and consensus amongst such a disparate and large committee.

The NWT CEAMF consists of the following major components:

- vision and objectives;
- land use planning;
- baseline studies and monitoring;
- research;
- audit and reporting;
- project-specific screening, environmental assessment and review;
- regulation and enforcement;
- information management;
- CEAMF coordination; and
- NWT Cumulative Effects Assessment and Management Framework.

Additional information can be found at the following URL:

http://199.247.124.123/ceam/00_FrameSet.htm

Northern East Slopes Sustainable Resource and Environmental Management Strategy

The Alberta Ministry of Sustainable Resource Development and other provincial departments established a Northern East Slopes Strategy (NES) in 1999 to address concerns about multiple land uses along the north ranges of Alberta's foothills (approximately east of Jasper National Park). Grazing, timber harvesting, mining, hunting, and energy exploration and development all occur in this region. A primary purpose of this initiative is to coordinate the development of an Integrated Resource Use Plan among many different governments, departments, and land users.

A Regional Steering Committee, consisting of NES members and representatives of local communities, has published an Interim Strategy report. Following community consultation, a planning process was identified that included the following components:

- establishment of a regional vision;
- identification of values and goals;
- development of indicators;
- identification of regional resource management issues;
- identification of resource management objectives;
- collection of baseline information, forecasting of future resource management scenarios, and selection of suitable options;
- development of strategies to achieve objectives;
- implementation of strategies through regional initiatives; and
- improvement of strategies through implementation, measurement, and monitoring.

Additional information can be found at the following URL:
http://www3.gov.ab.ca/env/regions/nes/strategy.html.

Appendix C: Workshop Notes

A two-day workshop was held during 30 and 31 January 2002 in Fort St. John. The workshop brought together participants from:

- provincial government: BC Oil and Gas Commission, Ministry of Energy and Mines; Ministry of Forests; Ministry of Sustainable Resource Management; Ministry of Water, Land and Air Protection; Muskwa-Kechika Management Board;
- First Nations: Fort Nelson First Nation Kaska Dene Council, Prophet First Nations;
- industry: Canadian Association of Petroleum Producers; Canadian Natural Resources Ltd.; Westcoast Energy Inc.;
- non-government organizations: Peace Habitat and Conservation Endowment Trust;
- academia: University of Northern BC; and
- consulting firms: Round River Consulting; Salasan Associates.

The workshop had two general objectives:

1. Disseminate information to participants about cumulative effects assessment and management, and about the project objective of developing a Cumulative Effects Assessment and Management Framework (CEAMF) for northeast BC. This included:

- providing background information on cumulative effects and on the project so all participants had a common understanding of the issues, and of the goals and objectives of the project;
- providing an overview of the components of the project: Framework, Case Studies, and Screener;
- presenting some of the challenges of doing cumulative effects assessment (e.g., selecting spatial and temporal boundaries), and engaging the participants in a discussion about these issues; and
- linking the CEAMF to other processes in northeast BC (e.g., LRMP processes, pre-tenure planning), and seeking input from the participants about our understanding of the linkages.

2. Elicit responses from participants about the approach, the data used, the analysis employed, and the preliminary conclusions. This included:

- presenting the data that were assembled and verifying it through discussions with the participants; and
- presenting a preliminary analysis and asking the participants to critically assess the analytical methods. We presented the hot spot maps developed by each discipline specialist and discussed with the participants the methodology employed and the preliminary conclusions derived.

Day One of the workshop focused on laying the groundwork for developing a CEAMF. This included presentations by the project team on: cumulative effects assessment; land use trends, planning and management; project overview; CEAMF as an overarching approach; case studies; regional database development; and discipline specific approaches to regional cumulative effects assessment covering air, terrain and soil, aquatic systems, vegetation, wildlife, resource use, and indigenous knowledge.

During Day Two, the workshop participants were divided into three breakout groups to facilitate more detailed discussions on the themes: Building Blocks of the CEAMF, and Options for Implementation of the CEAMF. Key discussion topics included:

Scale and Scope

Nested scales
- project level
- landscape level
- strategic/operational level
- subregional level
- regional level (e.g., LRMP)

Data Needs and Management

Data access
- cost of incorporating indigenous knowledge
- data exchange and agreement protocols
- mandatory requirement of industry
- inappropriate use of disseminated database

Historical activity

Automatic updating and relevancy

RIC standards for format consistency and quality control

Full disclosure of limitations and assumptions of data

VECs, Thresholds, and Hot Spots

VECs based on existing plans

Connectivity

Value of wilderness

Detailed disturbances expressed in terms that relate to thresholds (i.e., degree of impact on values)

Establishing spatial/temporal boundaries based on hot spots

Using hot spots to identify pristine, sensitive, and ecologically valuable areas against all land use pressures

Accommodating uncertainty

CEAM Framework

Assessment and management

Consistently applying the Framework to all sectors

Including the Framework as part of a planning process

Relating the Framework to varied planning horizons and planning processes (e.g., LRMP, pre-tenure planning)

Predictive component

Phased implementation

Adaptive monitoring

Appendix D: Database Description

A reliable information base is critical to a CEA. To accurately determine the impact of a development and mitigate its associated effects (e.g., utilize existing rights-of-way) on the landscape, existing infrastructure and land use information must be available. To serve as a tool in the preparation of CEAs, a regional database, consisting of a variety of environmental and topographic data was developed for the study area. The database consists of spatial coverages and related attribute tables at a variety of scales, and was assembled from files available from the Ministry of Sustainable Resource Management (MSRM); Ministry of Forests (MOF); and the Oil and Gas Commission (OGC). The database includes only those data that were available for most of the study area, and were free of charge to MSRM and the OGC. The database includes an assembly of data concerning:

- land use;
- disturbances (human activities and industrial development);
- wildlife habitat;
- rare and endangered species;
- fish distribution;
- soils and terrain;
- topographic base data (at scales of 1:1,000,000; 1:250,000; and 1:20,000);
- air photos;
- management boundaries;
- biogeoclimatic data;
- terrestrial ecosystem mapping;
- watersheds;
- protected areas; and
- place names.

In addition to the data types listed above, a number of derivative datasets were developed to generate seamless coverages for a specific theme for the entire study area, and to analyze and summarize data (e.g., for creating the hot spot maps and various density maps). These coverages and their attribute tables have been incorporated into the regional database provided.

The database represents the most current digital information base for the study area; however, users of the data should be aware of its limitations:

- The purpose of the database is to provide a regional overview of both the data available and the environmental characteristics of the study area. If a detailed CEA is being conducted, users should verify that the data is the most current, and determine if more detailed information is available for their specific area of interest.

- As mentioned above, the data have been provided at a variety of scales. Users should be aware of the consequences of mixing data at different scales, and should select a working scale appropriate for the spatial extents of their particular development.

Data layers presently found in the database are listed in Table D-1.

Table D-1. CEAMF Database: Current GIS Data

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
Air Quality				
Airdnsty	Air quality density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 1)
Air Photos				
rec####-19##	Rectified (greyscale) air photos (TIF) from 1950, 1970, & 1987	variable 1:15k to 1:40k	TIFF	MSRM
Agriculture				
Btmdstrb	BTM residential-agricultural mix	1:250k	SHP poly	MSRM
Btmdstrb	BTM rangeland	1:250k	SHP poly	MSRM
Btmdstrb	BTM cultivated land	1:250k	SHP poly	MSRM
Bei_cultivation	>= 50% Cultivated Field BEI	1:250k	SHP poly	MSRM
Biogeoclimatic Data				
MK_BEC	Biogeoclimatic zones clipped to M-K study area	1:250k	SHP poly ARCInfo poly	MSRM Data Clipped to Study Area
qes_bc	Ecosection coverage including ecodomain, ecodivision, ecoprovince, ecoregion	1:250k	ARCInfo poly	MSRM
Mk_qbei	Broad Ecosystem Inventory	1:250k	SHP poly	MSRM Data Clipped to MK Study Area
BTM	Baseline Thematic Mapping	1:250k	SHP poly	MSRM
Boundaries				
mk20nov00	Boundary – M-K management area from LUCO	1:250k	ARCInfo arc	MSRM
mk_study_bnd	Boundary – study area as	1:250k	ARCInfo	MK Management

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
	created by AXYS from project specs		poly	Area (from MSRM) and 1:250,000 provincial border merged to develop study area polygon
qrmz_jo, qrmz_fn, qrmz_mac	Resource Management Zones for Ft. St. John, Ft. Nelson, Mackenzie	1:250k	ARCInfo poly	MSRM
slrmp_bc	Land Resource Management Plan boundary	1:600k	ARCInfo poly	MSRM
Btfl_bc	Tree Farm Licence boundaries	1:2M	ARC poly	MSRM
Qmu_bc	MOE management units	1:250k	ARCInfo poly	MSRM
Btsa_bc	TSA boundaries	1:2M	ARCInfo poly	MSRM
Sfds_bc	Forest District boundaries	1:1M	ARCInfo poly	MSRM
Brgd_bc	Regional Districts	1:2M	ARCInfo poly	MSRM
Indian_bands	Preliminary Indian Band boundaries	unknown	SHP line	MSRM
CDC Data				
arebr_bc	CDC - Rare and Endangered Species, Element Occurrence Buffered Points	arbitrary	SHP poly ARCInfo poly	MSRM
areor_bc	CDC - Rare and Endangered Species, Element Occurrence Areas	arbitrary	SHP poly ARCInfo poly	MSRM
areop_bc	CDC Rare and Endangered Species, Element Occurrence Points	arbitrary	SHP point ARCInfo point	MSRM
aresr_bc	Rare and Endangered Species, CDC Sites	arbitrary	SHP poly ARCInfo poly	MSRM
Crown Land				
http://www.elp.gov.bc.ca/clrs/	Crown Land Registry web page			

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
DEM				
Elev_250	250 m elevation grid from NTS mass points		ArcView GRID	MSRM data merged & clipped to study area
coarse			ArcView GRID	MSRM data merged & clipped to study area
coarse_grid			ArcView GRID	MSRM data merged & clipped to study area
mk_dem_cov			ArcView GRID	MSRM data merged & clipped to study area
mk_grd			ArcView GRID	MSRM data merged & clipped to study area
mk_grid			ArcView GRID	MSRM data merged & clipped to study area
ne_bc			ArcView GRID	MSRM data merged & clipped to study area
north			ArcView GRID	MSRM data merged & clipped to study area
northern_bc_dem.shp			SHP poly	MSRM data merged & clipped to study area
mk_dem_coarse.shp			SHP poly	MSRM data merged & clipped to study area
Disturbance Coverages				
distnsv2	Combined disturbances (no seismic lines)	1:250k	SHP poly	Merged disturbances from individual map sheets
Fisheries				
qfshlu_mac	Fish Units for the Mackenzie LRMP	1:250k	ARCInfo	MSRM
qgray_mac	Arctic Greyling distribution in Mackenzie Forest District	1:250k	ARCInfo	MSRM
arc_grayling_hotspot_area	Arctic Grayling hot spot coverage	1:250k	SHP poly	Diversified Services
bull_trout_hotspot_area	Bull Trout hot spot	1:250k	SHP poly	Diversified

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
	coverage			Services
Critical-habitat-fish	Critical fish habitat	unknown	SHP point	Diversified Services
http://www.bcfisheries.gov.bc.ca/fishinv/fishinfobc.html	FishInfo BC			MAFF
Forestry				
thlb_djo thlb_dfn thlb_dmk	Timber harvest for Ft. St. John, Ft Nelson, MacKenzie Districts, and Cassiar ftp://ftpprg.env.gov.bc.ca/pub/outgoing/srm/rii/arc/landuse/thlb	unknown	ARCInfo E00 interchange fomat	MSRM
Forest Cover	Forest cover	1:20k	ARCInfo poly	MSRM
Btmdstrb	Recently burned	1:250k	SHP poly	MSRM
Btmdstrb	Selective logging	1:250k	SHP poly	MSRM
Btmdstrb	Recent logging	1:250k	SHP poly	MSRM
qndt_r7	Natural Disturbance Types for MOE Region 7	1:250k	ARCInfo poly	MSRM
btfl_bc	Tree Farm Licences for BC	2 million	ARCInfo poly	MSRM
btsa_bc	Timber Supply Areas for BC	2 million	ARCInfo poly	MSRM
http://www.for.gov.bc.ca/ftp/Prince_George_Region/!Regional_Office/external/!publish/ArcInfo_warehouse/				
Hillshade				
mk_mos2.jpg	Muskwa-Kechika hillshade mosaic JPG	1:250k	JPG image	Hillshade derived from provincial DEM
mk_mos2	Muskwa-Kechika hillshade mosaic GRID	1:250k	ARC GRID	Hillshade derived from provincial DEM
*.jpg	Over 200 georeferenced JPGs for entire province (on CD)	unknown	JPG image	MSRM
Urban / Industrial				
Btmdstrb	Mining	1:250k	SHP poly	MSRM
Btmdstrb	Selective logging	1:250k	SHP poly	MSRM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
Btmdstrb	Recent logging	1:250k	SHP poly	MSRM
Btmdstrb	BTM urban areas	1:250k	SHP poly	MSRM
Bei_urban	Urban areas derived from BEI polys	1:250k	SHP poly	MSRM data merged & clipped to study area
NTS_Mine	Mine points from NTS	1:250k	SHP poly	MSRM data merged & clipped to study area
NTS 094A-094P 104I & 104P				
qctr	Contour lines	1:250k	ARCInfo arc	MSRM
qcul	Cultural points and lines	1:250k	ARCInfo arc & point	MSRM
qcvr	Land cover	1:250k	ARCInfo arc	MSRM
qmisc	Miscellaneous features	1:250k	ARCInfo arc	MSRM
qntl	Mapsheet neatlines, tics, and grids	1:250k	ARCInfo arc & point	MSRM
qsrf	Surficial geology and soil cover	1:250k	ARCInfo arc	MSRM
qtrn	Transportation (pipelines, power, rail, road, air, ferry routes)	1:250k	ARCInfo arc	MSRM
qtxt	Annotation text	1:250k	ARCInfo anno	MSRM
qwtr	Surface water	1:250k	ARCInfo arc	MSRM
qdem	Digital Elevation Model	1:250k	ARCInfo point	MSRM
Oil & Gas				
All_pipelines	Oil/gas pipelines from Oil & Gas Commission	unknown	SHP line	OGC
All_wells	Oil/gas wells from Oil & Gas Commission	unknown	ARCInfo point	OGC
Ogc_wells_clipt	Oil/gas wells from Oil & Gas Commission	unknown	SHP point	OGC data clipped to study area
seismic.dgn	Seismic lines, points, & polys for Region 7	unknown	MicroStation design	MSRM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
			file	
Seismic	Seismic lines	unknown	SHP line	MSRM
Seisdens	Seismic line density grid	1:250k	ARCInfo GRID	MSRM
NTS_well	Oil/gas well points from NTS	1:250k	SHP point	MSRM data merged & clipped to study area
NTS_Facility	Oil/gas facility points from NTS	1:250k	SHP point	MSRM data merged & clipped to study area
Pipeline	Oil/gas pipelines from NTS	1:250k	SHP line	MSRM data merged & clipped to study area
wllden3k	Oil/gas well density (3 km neighborhood)	1:250k	ARCInfo GRID	Derivative analysis (Note 1)
Welldens	Oil/gas well density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 1)
Parks & Protected Areas				
Tpas_bc	Protected Areas	1:20k	ARC poly	MSRM
pa5aug99	Protected Areas from MOE	unknown	ARCInfo poly	MSRM
tpas_prg	Protected Areas for Prince George MOE District	1:20k	ARCInfo poly	MSRM
tppa_gl2	Goal 2 proposed Protected Areas for Ft. St. James LRMP	1:20k	ARCInfo poly	MSRM
Nts_camppicnic	Campsites and picnic sites from NTS	1:250k	SHP point	MSRM data merged & clipped to study area
Places & Names				
BC_Places	Towns and place names		SHP point	MSRM
Major_Places	Cities and place names		SHP point	MSRM
bcmj_bc	BC major places and names		ARCInfo point	MSRM
LUCONAME	LUCO place names		ARCInfo annotation	LUCO
Slope				
mk_slope	Slope coverage from DEM (clipped to study area)	1:20k	SHP poly	Generated in ArcInfo from provincial DEM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
Smoothed Densities				
Marsh	Smoothed marsh density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 2)
Streams	Smoothed stream density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 3)
Transprt	Smoothed transportation density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 3)
Wells	Smoothed well density grid	1:250k	ARCInfo GRID	Derivative analysis (Note 1)
Soils				
Bcc002_albers	Soil Landscapes of Canada (SLC)	1:1M	ARC poly	Agriculture & Agri-Food Canada: Canadian Soil Information System
eroshaz2	Erosion hazard grid	1:250k	ARCInfo GRID	Derivative analysis (Note 4)
soils_terrain	Soil terrain coverage	unknown	SHP poly	Agriculture & Agri-Food data clipped to study area
Terrestrial Ecosystem Mapping				
ltem_idx	TEM index coverage (for 50k TEM projects) Smith/Fishing 97/98 Liard River Hotsprings Dunedin 97/98 LaBiche 96/97 Sandy Cr 97/98 Snake/Sahtenah 97/98 Besa/Prophet 97/98	1:50k	ARCInfo poly	MSRM
ttem_idx	TEM index coverage (for 20k TEM projects) Trutch Cr Akie/Pesika	1:20k	ARCInfo poly	MSRM
tecp_aki	TEM polygons for Akie/Pesika project	1:20k	ARCInfo poly	MSRM
teci_aki	TEM field sampling points for Akie/Pesika	1:20k	ARCInfo point	MSRM
lecp_bes	TEM polygons for	1:50k	ARCInfo	MSRM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
	Besa/Prophet project		poly	
leci_bes	TEM field sampling points for Besa/Prophet	1:50k	ARCInfo point	MSRM
lecp_dun	TEM polygons for Dunedin project	1:50k	ARCInfo poly	MSRM
leci_dun	TEM field sampling points for Dunedin	1:50k	ARCInfo point	MSRM
lecp_bic	TEM polygons for LaBiche project	1:50k	ARCInfo poly	MSRM
leci_bic	TEM field sampling points for LaBiche	1:50k	ARCInfo point	MSRM
lecp_san	TEM polygons for Sandy Creek project	1:50k	ARCInfo poly	MSRM
leci_san	TEM field sampling points for Sandy Creek	1:50k	ARCInfo point	MSRM
lecp_sv	TEM polygons for Smith Vents project	1:50k	ARCInfo poly	MSRM
leci_sv	TEM field sampling points for Smith Vents	1:50k	ARCInfo point	MSRM
Traditional				
aems_bc	Pollution prevention monitoring sites	arbitrary	SHP point	MSRM
com_watshd	Community watersheds in BC	unknown	SHP line	MSRM
hydrometric	Hydrometric survey stations	unknown	SHP point	MSRM
qsit_bc	Contaminated Sites Registry	1:250k	SHP point	MSRM
snow-pillowa	Active snow pillow locations	unknown	SHP point	MSRM
wella	Observation well location	unknown	SHP point	MSRM
wins_a	Points of diversion	unknown	SHP point	MSRM
http://www.archaeology.gov.bc.ca/	MSRM Archaeology web page			MSRM
Transportation				
BC_rail_albers83	DCW rail	1 million	SHP line	Digital Chart of the World
BC_road_albers83	DCW roads	1 million	SHP line	Digital Chart of the

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
				World
road_main_polyline	Roads		SHP line	MSRM
mk-dcw-road.shp	DCW roads in M-K study area	1 million	SHP line	MSRM Data Clipped to Study Area
bcrailg	National Atlas Rail Lines	2 million	ARCInfo arc	MSRM
bcroadg	National Atlas Roads	2 million	ARCInfo arc	MSRM
NTS_roads	Roads/tracks from NTS	1:250k	SHP line	MSRM data merged & clipped to study area
NTS_trail	Trails from NTS	1:250k	SHP line	MSRM data merged & clipped to study area
NTS_rail	Rail lines from NTS	1:250k	SHP line	MSRM data merged & clipped to study area
NTS_airports	Airport, heliport, etc. from NTS	1:250k	SHP point	MSRM data merged & clipped to study area
TRIM				
TRIM 094A051-100 094H001-050	TRIM data can be accessed through MSRM contractor's FTP site: http://www.elp.gov.bc.ca/gis/trimcont/ *Located in the GIS source directory*			
tctr	Contour lines	1:20k	ARCInfo arc	MSRM
tcul	Cultural points and lines	1:20k	ARCInfo arc & point	MSRM
tcvr	Land cover features	1:20k	ARCInfo arc	MSRM
tmisc	Miscellaneous features	1:20k	ARCInfo arc	MSRM
tsrf	Surficial geology and soil cover	1:20k	ARCInfo arc	MSRM
ttrn	Transportation (pipelines,	1:20k	ARCInfo	MSRM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
	power, rail, road, air, ferry routes)		arc	
ttxt	Annotation text	1:20k	ARCInfo annotation	MSRM
twtr	Surface water	1:20k	ARCInfo arc	MSRM
tdem	Digital Elevation Model	1:20k	ARCInfo generate	MSRM
Vegetation				
mkqbei_v3	Vegetation classification	1:250k	SHP poly	MSRM data clipped to study area
Veghstrc3	Vegetation hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)
Water				
bc_drain_albers83	DCW rivers, lakes, and streams	1 million	ARCInfo poly	Digital Chart of the World
bc_drain_albers83.shp	DCW rivers, lakes, and streams	1 million	SHP line	Digital Chart of the World
dnnet	DCW rivers, lakes, and streams (dd)	1 million	ARCInfo arc & poly	Digital Chart of the World
bcdraing	National Atlas river, lakes, etc. (dd)	2 million	ARCInfo poly	National Atlas
qrlw_bc	NTS rivers, lakes, and wetlands for BC	1:250k	ARCInfo arc & poly	MSRM
qwtr_mk	NTS rivers, streams for Muskwa-Kechika (1:250 nts features appended)	1:250k	ARCInfo arc	MSRM data merged & clipped to study area
lakes_alb1mil.shp	DCW lakes and reservoirs for all of BC	1 million	ArcView poly shape	Digital Chart of the World
mk-dcw-river.shp	DCW rivers, streams for Muskwa-Kechika study area	1 million	ArcView arc shape	Digital Chart of the World clipped to study area
qglr_bc	NTS glacier and water features for BC	1:250k	ARCInfo arc	MSRM
taqf_bc	Groundwater aquifers in BC	1:20k	ARCInfo poly	MSRM
Water Quality				
rivers	River grid	1:250k/ 125m cell size	ARCInfo GRID	Generated from vector river coverage

Coverage Name	**Description & Source**	**Scale**	**Type & Projection**	**Source/ Custodian**
river_c5	River density grid (5 km neighborhood analysis)	1:250k	ARCInfo GRID	Derivative analysis (Note 3)
marsh_c5	Marsh density grid (5 km neighborhood analysis)	1:250k	ARCInfo GRID	Derivative analysis (Note 2)
lakes	Lake GRID	1:250k/ 125m cell size	ARCInfo GRID	Generated from vector lake coverage
lakes_c5	Lake density grid (5 km neighborhood analysis)	1:250k	ARCInfo GRID	Derivative analysis (Note 2)
Watersheds				
Watershed Atlas	*Watershed boundaries from MOE for the following watersheds: Beaver, Coal, Dunedin, Finlay, Fontas, Fox, Frog, Gataga, Hay, Ingenika, Kahntah, Kotcho, Lwr Beatton, Lwr Ft Nelson, Mid Ft Nelson, Upr Ft Nelson, Lwr Halfway, Upr Halfway, Lwr Kechika, Upr Kechika, Lwr Muskwa, Mid Muskwa, Upr Muskwa, Lwr Peace, Upr Peace, Lwr Petitot, Upr Petitot, Lwr Prophet, Mid Prophet, Upr Prophet, Lwr Sikanni, Upr Sikanni, Milligan, Ospika, Sahdoanah, Sahtaneh, Shekilie, Toad, Toodoggone, Tsea, Turnagain, Upr Liard, Liard*		*On CD*	
lwsl_*	Rivers, Lakes, Wetlands – BC watershed atlas	1:50k	ARCInfo poly	MSRM
lwss_*	Stream network layer – BC watershed atlas	1:50k	ARCInfo arc	MSRM
lwsd_*	Watershed polygons – BC watershed atlas	1:50k	ARCInfo poly	MSRM
Wildlife/Habitat				
ALALHSPT	Moose hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)
MAAMHSPT	Marten hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
			GRID	
RATAHSPT	Caribou hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)
URARHSPT	Grizzly Bear hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)
WARBHSPT	Warbler hot spot grid	1:250k	ARCInfo GRID	Derivative analysis (see Appendix E)
caribou_habitat	Combined caribou habitat for M-K	1:250k	SHP	MSRM data merged & clipped to study area
qcar_mac	Caribou habitat suitability for Mackenzie LRMP	1:250k	ARCInfo poly	MSRM
qmos_mac	Moose habitat for Mackenzie LRMP	1:250k	ARCInfo poly	MSRM
qcarma_mac	Mackenzie Forest District caribou management areas	1:250k	ARCInfo poly	MSRM
qcms_mac	Caribou management strategy, Mackenzie LRMP	1:250k	ARCInfo poly	MSRM
qer_bc	Ecological reserves, wild man. & rec. areas for BC	1:250k	ARCInfo poly	MSRM
qgriz_mac	Grizzly Bear habitat for Mackenzie LRMP	1:250k	ARCInfo poly	MSRM
qgot_r7	Guide outfitter territory	1:250k	ARCInfo poly	MSRM
qtrp_r7	Trapper territory	1:250k	ARCInfo poly	MSRM
llehb_bc	Limited Entry Hunting Zone: Bison	1:50k	ARCInfo poly	MSRM
llehc_bc	Limited Entry Hunting Zone: Caribou	1:50k	ARCInfo poly	MSRM
llehd_bc	Limited Entry Hunting Zone: Mule Deer	1:50k	ARCInfo poly	MSRM
llehe_bc	Limited Entry Hunting Zone: Elk	1:50k	ARCInfo poly	MSRM
llehg_bc	Limited Entry Hunting Zone:	1:50k	ARCInfo poly	MSRM
llehm_bc	Limited Entry Hunting Zone: Moose	1:50k	ARCInfo poly	MSRM
llehs_bc	Limited Entry Hunting Zone: Mountain Sheep	1:50k	ARCInfo poly	MSRM
llehw_bc	Limited Entry Hunting	1:50k	ARCInfo	MSRM

Coverage Name	Description & Source	Scale	Type & Projection	Source/ Custodian
	Zone: White-tailed Deer		poly	
llehz_bc	Limited Entry Hunting Zone: Grizzly Bear	1:50k	ARCInfo poly	MSRM
http://www.elp.gov.bc.ca/rib/	MSRM Resource Inventory Branch			
http://www.for.gov.bc.ca/research/	Ministry of Forest Research Branch			
http://www.for.gov.bc.ca/resinv/homepage.htm	MSRM Terrestrial Information Branch			

Derivative Analysis Descriptions

Note 1 – Density of point features methodology

Applies to the following coverages:

- Air quality density
- Oil and gas well density
- Smoothed well density

The development of each of the derived point feature density coverages involved the following steps:

1. Point features were converted to a raster coverage (grid) based on a 125 metre cell size.
2. The grid was reclassified with each cell being assigned a value of 0 (no data) or 1 (data present). In the case of the air quality density the air emission value was used for the cell value.
3. The number of point features being summarized per pixel of raster data was determined (e.g., the total number of point features divided by the number of raster cells).
4. The reclassified grid developed in step 2 was multiplied by the factor determined in step 3 to generate a density statistic.
5. The raster-based cells are aggregated to a larger grid cell size (e.g., 5 kilometres). During this step the number of points calculation of the aggregated cells is summed.
6. For some datasets a neighborhood analysis is conducted to smooth the data for cartographic purposes. This involved determining the average density within a 15 kilometre radius.

Note 2 – Density of polygon features methodology

Applies to the following coverages:

- Smoothed marsh density
- Lake density (5 km analysis)
- March density (5 km analysis)

The development of each of the derived polygon density coverages involved the following steps:

1. Vector features (polygons) were converted to a raster coverage (grid) based on a 125 metre cell size.

2. The grid was reclassified with each cell being assigned a value of 0 (no data) or 1 (data present);
3. The area of polygonal features being summarized per pixel of raster data was determined (e.g., the total area of polygonal features divided by the number of raster cells)
4. The reclassified grid developed in step 2 was multiplied by the area factor determined in step 3 to generate a density statistic;
5. The raster-based cells are aggregated to a larger grid cell size (e.g., 5 kilometres). During this step the area calculation of the aggregated cells is summed;
6. For some datasets a neighborhood analysis was conducted to smooth the data for cartographic purposes. This involved determining the average density within a 15 kilometre radius.

Note 3 – Density of linear features methodology

Applies to the following coverages:

- Smoothed stream density
- Smoothed transportation density
- River density (5 km analysis)

The development of each of the derived linear density coverages involved the following steps:

1. Vector features (polylines) were converted to a raster coverage (grid) based on a 125 metre cell size;
2. The grid was reclassified with each cell being assigned a value of 0 (no data) or 1 (data present);
3. The length of linear features being summarized per pixel of raster data was determined (e.g., the total length of linear features divided by the number of raster cells)
4. The reclassified grid developed in step 2 was multiplied by the length factor determined in step 3 to generate a density statistic;
5. The raster-based cells are aggregated to a larger grid cell size (e.g., 5 kilometres). During this step the length calculation of the aggregated cells is summed;
6. For some datasets a neighborhood analysis is conducted to smooth the data for cartographic purposes. This involved determining the average density within a 15 kilometre radius.

Note 4 – Erosion hazard grid

The development of each of the erosion hazard grid involved the following steps:

1. Land use data was obtained from the Baseline Thematic Mapping (BTM) map series.
2. Agricultural and forestry related land uses were extracted from the BTM coverage.
3. A grid coverage was developed using a 125 m cell size depicting forest land.
4. A grid coverage was developed using a 125 m cell size depicting agricultural land.
5. The grids were reclassified with each cell being assigned a value of 0 (no data) or 1 (data present).
6. A slope grid was developed from the 1:250,000 scale provincial DEM.
7. The slope grid was reclassified based on slope classes for both agricultural and forest land uses.
8. Each land use grid was then multiplied by the appropriate slope classification grid to generate a land use specific erosion hazard coverage.
9. The two derivative erosion hazard grids were subsequently merged to yield an erosion hazard coverage for the study area.

Appendix E: Hot Spot Derivation

E.1 Hot Spot Maps: Definition and Use

Hot spot maps identify spatial interactions between Valued Ecosystem Components (VEC) and human disturbances. They help us quantify how vulnerable a given VEC is to a stressor (e.g., development activities). The primary goal of the hot spot maps is to identify those parts of the regional study area that have relatively high levels of remaining natural resources (e.g., wildlife habitat) which are currently experiencing high levels of human pressure. Hot spot maps serve the following functions:

- they allow for quick and easy identification of VECs that are potentially affected by existing or proposed development;
- they identify areas (i.e., hot spots) for monitoring, and thus, allow potential negative or positive trends in the environmental conditions of the region to be quantified (e.g., area statistics of potentially affected habitat can be calculated for different years and tracked over time). Examination of these trends allows environmental managers and planners to identify potential problem areas, and to develop priorities for management actions; and
- they allow sampling efforts to be focused on particular areas of interest (e.g., increase sampling in hot spot areas and sample to a lesser degree outside those areas), thereby increasing the efficiency and cost effectiveness of data-gathering programs.

E.2 Common Elements

Although the specific methodology to generate each hot spot map varies, as detailed in the following sections, fundamentally, hot spots are identified through the development of an interaction index between a defined VEC and disturbances in the region (including disturbances from non oil and gas activities). Common to all hot spot maps are the following basic steps:

- develop a map that depicts the spatial extent of the VEC (e.g., a wildlife habitat capability coverage);
- select the disturbance(s) that are affecting the VEC;
- establish a Zone of Influence (ZOI) for disturbances and develop a map that depicts the ZOI (note: the ZOI will be unique to the VEC in question);
- overlay the ZOI coverage with the VEC coverage to identify areas of interaction;
- develop an interaction matrix to quantify the degree of impact; and
- develop the hot spot map - a thematic map based on the classifications defined in the interaction matrix.

Many of the maps relied on a disturbance coverage that was generated for the study area, and used as a basis for defining a ZOI for each VEC. The following themes were used to generate the disturbance coverage:

- agriculture;
- residential/agriculture mix;
- range land;
- railways;
- roads;
- trails;
- pipelines;
- transmission lines;
- urban areas;
- recent logging;
- selective logging;
- oil and gas facilities;
- active airstrips;
- inactive airstrips;
- oil/gas wells;
- mining; and
- recreation areas.

Seismic line data is available for the study area; however, these data were not included in the disturbance coverage as many of the seismic lines are known to be 25-30+ years old, and therefore, will have revegetated naturally. Unfortunately, there is no date attribute in the seismic line coverage, and therefore, no way to identify older lines. Thus, this theme was excluded.

The hot spot maps generated for this project were based on existing applicable disturbances and a select number of VECs that were chosen as environmental indicators. The maps identify areas of potential concern within the regional study area, and can be used as a reference tool for assessing the general environmental conditions of the area, and for developing strategic planning.

The maps do not illustrate the *relative contributions* of different types of disturbances. This would only be possible by either mapping disturbance types individually and defining unique ZOI coverages for each disturbance type and respective VEC as a respective mapping exercise; or by weighting disturbances based on their predicted effects on a VEC relative to other types of disturbances. As the focus of the hot spot analysis was to illustrate areas of potential *cumulative* effects, individual disturbance types were not mapped.

It is important to note that the maps have been generated at a regional scale (i.e., 1:250,000), and thus, are highly suited to support regional planning or other initiatives. They should not be used for detailed planning and assessment in isolation of other, finer-scale information that is applicable to a precise area of interest (e.g., a proposed well site). However, in detailed, project-specific assessments, the hot spot maps could be used to help select indicator species, and to focus assessment efforts on the VECs that are potentially affected by a proposed development.

E.3 Map Derivation by Discipline

Hot spot maps developed as part of this study are listed in Table E-1. These are examples of the types of maps that could be generated using information in the regional database for selected VECs. This is not an inclusive list of all potential hot spot maps. The following sections describe the general methodology for preparing maps for each discipline. All maps were derived using a Geographic Information System (GIS).

Table E-1. Hot Spot Maps

Discipline	VEC	Disturbance	Hot Spot Map
Soils and Terrain	Soil Acid Sensitivity	SO_2 emissions	Soil Acid Sensitivity
	Erosion Risk	ZOI for soils and terrain	Erosion Risk
Vegetation	Vegetation	ZOI for vegetation	Vegetation VECs
Wildlife	Grizzly Bear	ZOI for grizzly bear	Grizzly Bear Habitat Capability
	Moose	ZOI for moose	Moose Habitat Capability
	Marten	ZOI for marten	Marten Habitat Capability
	Warblers	ZOI for warblers	Warbler Habitat Capability
	Caribou	ZOI for caribou	Caribou Winter Habitat
Aquatic Ecosystems	Aquatic Ecosystems	Not applicable	Aquatic Ecosystems
Air Quality	Air Quality	Well Head Density Sulfur Emissions	Well Head Density Sulfur Emissions

Air Quality

Two criteria were used for creating the air quality land use hot spot maps – well head density and sulfur-weighted well head density.

For the well density map (Figure 3-10), each well was assigned an arbitrary ZOI of 3 km. Once the 3 km ZOI was applied, the number of wells per km^2 could be classified for the entire study area (ranging from areas containing 0 wells per km^2 to areas with up to 100 wells per km^2). Figure 3-10 thus provides a rough idea of where cumulative impacts may occur under the current development scenario.

Figure 3-11 is a sulfur-weighted plot that was created by multiplying the well density by the H_2S content of the well. Figure 3-11, then, is a better illustration of potential cumulative impacts on air quality because the amount of SO_2 released from a well is directly proportional to the amount of H_2S in the gas. This map was generated by using the ZOI spatial coverage generated in Figure 3-10, and weighting the coverage with the emissions data. To do this, a grid was developed that depicted the emission value per well. A derivative grid was then developed summing the total emission level within each square kilometre. A neighbourhood analysis was then run to sum the data for the 3 km ZOI, and the derivative grid was themed based on the emission levels.

Soils and Terrain

Acid Sensitivity

Risk ratings for sensitivity of soils to potential acid inputs (PAI) were assigned based on the ability of the regional soils to buffer the impacts of soil acidification. High risk soils have low buffering capacities due to low pH levels, low cation exchange capacities, and relatively low calcium reserves. They are primarily derived from coarse textured fluvial or glaciofluvial parent materials, and are classified as Dystric or Sombric Brunisols. Eutric and Melanic Brunisols are considered to be moderately sensitive to PAI, and are also developed on glaciofluvial material. All other soil types exhibit higher buffering capacities, and thus, are considered low risk to PAI.

To develop the sensitivity polygons shown in Figure 3-13, soil data from the CANSIS 1:1,000,000 scale dataset were grouped based on the following classifications (Table E-2):

Table E-2. Soil Acid Sensitivity Classes

Sensitivity	Soil Type
High	Dystric and Sombric Brunisols
Moderate	Eutric and Melanic Brunisols
Low	All Others

Erosion Risk

Erosion risk categories were established using different criteria for agricultural and forestry land. With no litter layer and an absence of well-established vegetation rooting, agricultural soils are at greater risk of significant erosion on gentler slopes than are forest soils. Erosion risk values were assigned based on the classifications listed in Table E-3. To generate the map, a slope grid was developed from a Digital Elevation Model (DEM) for the study area that was generated from Terrain Resource Inventory Mapping (TRIM) data. Slope values were then reclassified according to the defined classes (Table E-3). The classified slope grid was subsequently overlaid with land use data from the Baseline Thematic Mapping (BTM) dataset to produce a derivative coverage that delineated erosion potential (Figure 3-14).

Table E-3. Soil Erosion Sensitivity Classes

Sensitivity	Agricultural Land Slopes	Forest Land Slopes
High	> 10 % (> 5°)	> 45 % (> 24°)
Moderate	6 - 9 % (3-5°)	30 - 45 % (16.5 - 24°)
Low	< 6 % (< 3°)	< 30 % (< 16.5°)

Aquatic Ecosystems

Data Limitations

Delineation of hot spots requires spatial and temporal information that describes links between VECs and cumulative effects of environmental stressors. Ideally, that data might include basic descriptions of pristine water quality or aquatic community composition and abundance. That data would include functional relationships that link changes in a VEC to some manipulation or disturbance. With these data and relationships, a map could be produced that showed the distribution of pristine lakes and streams based on chemical criteria, similar to that produced for an ecozone classification by Perrin and Blyth (1998). The map might also show the distribution of fish VECs (e.g., bull trout and grayling abundance, and critical rearing and spawning habitat). Zones of pristine wetlands, lakes, and streams, and zones where fish may be sensitive to disturbance might be considered hot spots where they coincide with existing or planned industrial activity.

Unfortunately, data required to produce these types of maps are generally lacking, particularly for water quality criteria within the study area. In development of the aquatic ecozone classification, Perrin and Blyth (1998) found a limited and clumped distribution of chemical data for surface waters in the entire northeast part of the province, which includes the project study area. Lake and stream data from the Peace Plains Aquatic Ecoprovince was distributed mainly near Fort St. John in the lower Beatton River and Peace River drainages, but there was no indication of water quality in headwaters. In the Taiga Plains Aquatic Ecoprovince, surface water data included only two observations of three parameters from small lakes in drainages of the lower Prophet River, Fort Nelson River, and Sikanni Chief River. All sites were in proximity to road access points from Fort Nelson and the Alaska Highway. In the Muskwa Ranges, which characterize the

MKMA, only two observations were available from lakes in drainages of the Fox River and upper Muskwa River. These data do not provide adequate basic descriptive evidence of chemical characteristics of any type of surface water throughout the study area, mainly because sample sizes are too small to yield adequate precision, most drainages have not been sampled, and no time course measurements are available for examining temporal or seasonal variation.

Data describing fish presence and distribution is somewhat better, largely because fish end-points have been of particular interest for both resource management agencies and industry. In recent years, fish and fish habitat inventory funded by Forest Renewal British Columbia, and environmental impact assessments funded by various industrial interests have greatly expanded our knowledge of fish distribution within the study area. While information gaps exist, point sampling for fish presence has occurred widely across the study area (e.g., by MWLAP, Fort St. John). Data resulting from past fish surveys have provided evidence of physical features of aquatic habitat that support indigenous fish species.

The vulnerability of some regional fish species, coupled with the deficiency in water quality information, pointed to the use of fish to describe cumulative impact hot spots for fish and water quality of aquatic ecosystems. The premise here was that fish (mainly bull trout and Arctic grayling) as VECs are, in fact, indicators of water quality. This decision was based on well-known evidence that fish are sensitive indicators of change to physical and chemical conditions in water, particularly change associated with land disturbance (e.g., acute change in suspended solids concentration) and exposure to effluents or discharges associated with human and industrial activity (CCME 1999). In fact, fish species are used as standard organisms for testing effects of contaminants in fresh water (e.g., EPS 1992).

There are currently no databases available with which rules may be applied to search for certain combinations of habitat features and fish distributions, and to examine their associations with industrial activity. It is possible to suggest, in a generalized sense, that fish abundance is some inverse function of obvious independent variables like density of roads or exploration drilling sites. These developments may affect fish populations by affecting water quality and fish abundance due to changes in suspended sediment loads or contaminant discharges. Developing human access into the mainstem corridors of major river systems also puts adult populations of sport fish at risk from increased angling pressure (both legal and illegal). These independent variables might then be used as surrogates for predicting distribution of fish, or even water quality; however, this approach may provide misleading information as it is not based on actual knowledge of fish distributions or characteristics of water quality, and thus, could contain serious errors.

A mechanism comprising part of the former Local Area Agreement implemented within a portion of the Fort St. John Forest District is currently being developed as part of a Best Management Practices protocol by MWLAP, the OGC, and industry. This mechanism will use physical and mapping features to default non fish-bearing reaches, and focus on areas of fisheries concern using a 1:20,000 TRIM base. It is, however, of limited utility for broad scale application using the NTS map base.

Aquatic Ecosystem Hot Spot Map

The approach used to delineate the aquatic ecosystem hot spots (Figure 3-16) was to draw polygons around drainages that contain important habitat for VECs (i.e., bull trout and Arctic grayling) where those drainages occur in the vicinity of current or planned industrial activity.

Drainages or groups of drainages where sampling data indicates moderate to high densities of each VEC species were highlighted to produce distribution polygons for each VEC. The VEC densities were considered in relative terms based on their occurrence at multiple sampling points within drainages or groups of drainages. Areas with little or no likelihood of industrial development in the near future, including provincial parks, protected areas, and portions of the MKMA not currently subject to pre-tenure planning, were excluded from the analysis.

Known and extrapolated bull trout and Arctic grayling distribution was used as an indicator of the presence of sensitive aquatic habitats. These habitats are generally characterized by riffle/pool morphologies originating on uplands where average gradients are greater than 0.5%, and where substrates are dominated by gravels and cobbles.

Hot spot polygons represent areas that currently have increased potential for conflict between industrial development and sensitive aquatic resources; they do not assume the absence of concern elsewhere. Hot spots derived from Arctic grayling distribution dominate upland portions of the Interior Plateau, while hot spots associated with bull trout presence occur in mountain and foothills terrain in the southwest portion of the study area. Hot spots for aquatic systems are generally larger than those for other VECs due to the fluidity of water resources and the potential repercussions of site-specific impacts spread across watersheds.

Water quality hot spots correspond to these polygons based on the assumption that present or potential land disturbance or effluent discharge associated with industrial development can affect both fish abundance and the chemical and biological characteristics of aquatic ecosystems.

Vegetation

The intersection of the vegetation ZOI with the occurrence of the three vegetation VECs (old-growth forests, wetlands, and rare units) was used to identify areas of concern related to the potential for cumulative effects from oil and gas exploration (Table E-4). Level of concern categories are defined as follows:

Some Concern: further disturbance has some implications for integrity of the VEC;

Hot Spot – Moderately Disturbed: further disturbance has serious implications for integrity of the VEC; and

Hot Spot – Highly Disturbed: present disturbance has seriously reduced integrity of the VEC; further disturbance compromises opportunities for recovery or restoration.

The vegetation hot spot map is shown as Figure 3-19.

Table E-4. Vegetation VEC Hot Spots: Assignment of Level of Concern Related to Potential for Cumulative Effects from Oil and Gas Exploration and Development

	Amount of Disturbance		
Vegetation VEC	**Low**	**Moderate**	**High**
Old-growth Forests	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed
Wetlands	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed
Rare Units	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed

Wildlife (Grizzly Bear, Moose, Marten, and Warblers)

Broad Ecosystem Inventory-(BEI) based wildlife habitat capability mapping at a scale of 1:250,000 was used to determine hot spots for four wildlife VECs: grizzly bear, moose, marten, and warblers (caribou, also identified as a VEC, is discussed below). Capability is the ability of a habitat, under optimal seral conditions, to support a given species, irrespective of that habitat's current seral condition (RIC 1999). A habitat capability rating is the value assigned to a habitat according to its potential to support a given species, compared to the best habitat in the province used by that species (RIC 1999). The habitat capability maps used in this project have a four-class rating scheme (1 – high, 2 – moderate, 3 – low, 4 – nil) as described in the British Columbia Wildlife Habitat Ratings Standards (RIC 1999).

The intersection of the relevant wildlife (grizzly bear, moose marten and warblers) ZOI coverage (with neighbour analysis) and habitat capability values was used to identify areas of concern relating to the potential for cumulative effects from oil and gas activity (Table E-5). Level of concern categories are defined as follows:

Negligible Concern: further disturbance has negligible implications for habitat capability;

Some Concern: further disturbance has some implications for habitat capability;

Hot Spot – Moderately Disturbed: further disturbance has serious implications for habitat capability; and

Hot Spot – Highly Disturbed: present disturbance has seriously reduced habitat capability; further disturbance compromises opportunities for recovery or restoration.

Results of wildlife hot spot mapping are shown in Figures 3-25 to 3-28.

Table E-5. Grizzly Bear, Moose, Marten, and Warbler Hot Spots: Assignment of Level of Concern Related to Potential for Cumulative Effects from Oil and Gas Exploration and Development

	Amount of Disturbance		
Habitat Capability Rating	**Low**	**Moderate**	**High**
Nil	Negligible Concern	Negligible Concern	Negligible Concern
Low	Negligible Concern	Some Concern	Some Concern
Moderate	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed
High	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed

Wildlife (Caribou Winter Habitat)

The BEI-based habitat capability information available for caribou is less appropriate for the boreal eco-type of woodland caribou. As an alternative, caribou winter habitat was used to determine caribou hot spots. Typical caribou winter habitat in northern BC, Alberta, and Alaska includes alpine areas, and open subalpine forests and upland forested areas that are 80 years or older (Anderson et al. 2000, Rettie and Messier 2000, Apps et al. 2001, Culling and Culling 2001, Szkorupa 2002). The categories used to describe stand age in the BEI database did not, however, permit this age distinction, so for the purpose of identifying hot spots at the regional scale, caribou winter habitat was identified using the following Broad Ecosystem Unit (BEU) types and structural stage (stand age) parameters:

- Forest (non-riparian) units >140 years old: Boreal White Spruce-Trembling Aspen (BA), Boreal White Spruce-Lodgepole Pine (BP), Englemann Spruce-Subalpine Fir Dry Forest (EF), Lodgepole Pine (LP), White Spruce-Subalpine Fir (SF), and Black Spruce-Lodgepole Pine (BL);
- Alpine units: Alpine Meadow (AM), Alpine Tundra (AT), Alpine Grassland (AG), and Alpine Shrubland (AS); and
- Open subalpine forest units >140 years old: Subalpine Fir-Scrub Birch Forest (FB), Subalpine Fir-Mountain Hemlock Wet Parkland (WP), and Englemann Spruce-Subalpine Fir Parkland (FP).

These parameters describe 'current' caribou winter habitat - i.e., winter habitat that is not necessarily in use at present, but does currently meet the criteria for caribou winter habitat (within the limitations described above). 'Potential' caribou winter habitat - i.e., forested habitats 140 years old or less that may be used as winter habitat in the future, was identified as follows:

- Forest (non-riparian) units ≤140 years old: same BEUs as described for current caribou winter habitat
- Open subalpine forest units ≤140 years old: same BEUs as described for current caribou winter habitat

The intersection of the caribou ZOI coverage with areas of current and potential caribou winter habitat was used to identify areas of concern relating to the potential for cumulative effects from oil and gas activities (Table E-6). Level of concern categories are defined as follows:

Negligible Concern: further disturbance has negligible implications for availability of caribou winter habitat;

Some Concern: further disturbance has some implications for availability of caribou winter habitat;

Hot Spot – Moderately Disturbed: further disturbance has serious implications for availability of caribou winter habitat; and

Hot Spot – Highly Disturbed: present disturbance has seriously reduced availability of caribou winter habitat; further disturbance compromises opportunities for recovery or restoration.

The caribou hot spot map is presented in Figure 3-29.

Table E-6. Caribou Winter Habitat: Assignment of Level of Concern Related to Potential for Cumulative Effects from Oil and Gas Exploration and Development

	Amount of Disturbance		
	Low	**Moderate**	**High**
Potential Winter Habitat	Negligible Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed
Current Winter Habitat	Some Concern	Hot Spot – Moderately Disturbed	Hot Spot – Highly Disturbed

Appendix F: Oil and Gas Project Assessment Matrices

A regulatory Environmental Impact Assessment (EIA) is typically comprised of the following five steps:

1. **Scoping**: the early identification of key aspects of the assessment, including issues of concern, valued ecosystem components (VEC), spatial boundaries, temporal boundaries, the project's impacts that lead to various effects, and other projects that are contributing cumulatively to the same effects;
2. **Analysis**: the prediction of effects of the project alone (project-specific effects), and in combination with the effects from other human disturbances (i.e., cumulative effects), using appropriate analytical tools (e.g., spatial and numerical modelling);
3. **Mitigation**: the identification of approaches to manage any negative effects by eliminating or reducing the effect (e.g., air emissions controls, minimization of cleared areas);
4. **Significance**: the evaluation of how important the residual effect is (i.e., after mitigation), based on appropriate criteria that establish the context in which that effect may be compared (e.g., regulatory guidelines, land use policies, scientific empirical evidence, levels of acceptable social change, thresholds); and
5. **Follow-up**: monitoring of the project to verify the implementation and effectiveness of mitigation, and to verify the accuracy of predicted effects.

Cumulative effects are addressed, to greater and lesser degrees, under each of these steps

The matrices on the following pages provide general and specific guidance for each of these steps in relation to seven components that are commonly examined in EIAs:

- Table F-1. Air Quality;
- Table F-2. Soils and Terrain;
- Table F-3. Aquatic Ecosystems;
- Table F-4. Vegetation;
- Table F-5. Wildlife;
- Table F-6. Land and Resource Use; and
- Table F-7. First Nations.

It is not the intent of this project to provide a detailed guide for proponents; however, these matrices could be used as part of a project-specific assessment to help identify:

- potential effects;
- candidate valued ecosystem and social components;
- useful analytical tools;
- appropriate effects mitigation measures;
- guidelines for significance determination (e.g., existing standards or thresholds); and
- options for follow-up and monitoring.

Use of the matrices to guide a project-specific cumulative effects assessment assumes that the assessor has taken care to identify all sources of potential disturbance within a defined spatial area (i.e., those in addition to the project to which the assessment applies). A Project Inclusion List (PIL) for the cumulative effects assessment is normally developed early in the assessment process. The PIL should include both existing projects and proposed projects (i.e., reasonably foreseeable projects for which some information is available, which normally happens when an application or public disclosure document is filed). Examples of local or regional projects that would be included in the PIL are:

- other oil and gas activities and facilities;
- mining activities and facilities;
- forestry activities;
- hydroelectric facilities and utilities;
- agricultural and livestock areas;
- transportation corridors, industrial access corridors, and other access routes;
- utility sites and corridors;
- residential communities;
- hunting and trapping areas and camps/cabins;
- tourism and recreation sites, trails, and camps; and
- human-caused and natural disturbances such as forest fires.

Ultimately, the PIL will reflect land use activities presently occurring (or proposed) within the local and regional study area in question.

The matrices should be used in combination with site-specific information and an understanding of site-specific issues and valued components in the area of application. Additionally, as part of the overarching Cumulative Effects Assessment and Management Framework (CEAMF), the matrices should be periodically updated to include new information (e.g., with regard to analytical tools, thresholds, etc.).

Detailed guidance on completion of the five steps in the assessment process is available from the *Cumulative Effects Assessment Practitioners Guide*, which can be purchased from the Canadian Environmental Assessment Agency or accessed from the agency's website: http://www.ceaa-acee.gc.ca/0011/0001/0004/index_e.htm.

Table F-1. Air Quality

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Air emissions resulting in air quality degradation may be caused by vehicle exhaust; road dust; fugitive dust emissions from vehicles; equipment exhaust; combustion products from chain saws, off-road vehicles, heavy-duty vehicles and road vehicles; emissions from camp heaters, generators and garbage burning; other waste disposal (incineration) • Odour impacts and non-lethal health effects may occur at levels below regulatory control limits	Air emissions resulting in air quality degradation may be caused by: • **S:** Emissions are from ground-based sources, and are relatively small in magnitude. Noise may be an issue if near settlements or sensitive wildlife areas • **E:** Well test flare emissions can be significant, especially if the well is producing sour gas. Local assessments are required for sour gas well test flaring if the H_2S content is greater than 5%. • **P:** Emissions are from well flaring during stimulation and maintenance operations; heater, compressor, cogeneration, and flare emissions at the batteries, gas processing, and straddle plants; and Sulphur recovery plant emissions. NOx, SO_2, and CO emissions can be significant • **PL:** Emissions can be produced from well blowdown operations that may be vented directly or flared and from compressor and cogeneration units. Compressor NOx, SO_2, and CO emissions can be significant
	VECs	• Combustion emissions include NO_x and CO with smaller amounts of VOC and PM • Fugitive emissions including PM and chlorinated compounds from garbage burning	• **E:** Well test flaring can produce significant amounts of SO_2 if sour gas is flared; odours are also produced • **P:** In some cases, the use of a sour fuel can produce SO_2 emissions • **P:** Fugitive plant emissions include HC and H_2S and other TRS compounds; sulphur recovery plants can produce SO_2 emissions and associated sulphur handling can produce PM and H_2S (TRS) emissions; visibility restrictions (fog/ice fog) due to H_2O emissions and odours are also produced • **PL:** Venting results in the release of HC emissions; flaring can result in SO_2 emissions; visibility restrictions (fog/ice fog) due to H_2O emissions also occur

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Spatial Boundaries		• **S:** Local effects are less than 100 m from the emission source • **E:** For flaring, maximum concentrations are expected to occur within 10 km, and may occur on any elevated terrain in the area • **P:** Maximum concentrations are expected to occur within 10 km, and may occur on any elevated terrain in the area • **PL:** Maximum concentrations are expected to occur within 10 km, and may occur on any elevated terrain in the area
	Temporal Boundaries		• **S:** Effects are periodic and short-term • **E:** Flaring tends to be short-term (~1 to 5 days). In the extreme, an under-balanced test may persist for ~30 days), simultaneous events in the same airshed should be avoided • **P:** Flaring emissions occur during startup, maintenance, shut down, and upset operations and tend to be short term; Plant emissions from combustions sources are continuous • **PL:** Venting and flaring operations are limited to startup, maintenance, and shut down periods, and are short term; compressor and cogeneration emissions from combustion sources are continuous
Analysis		• Understanding of local and regional emission sources, meteorology and terrain is required • Understanding of relevant ambient air quality objectives and risk factors is required • A large number of computer models are available to calculate emission plumes and emission concentrations for daily, monthly, and annual periods. All of these models require field data on emissions, as well as weather data	• **S:** Detailed analysis is not normally required unless frequency and intensity create the potential for significant impacts
Mitigation		• Site facilities in locations that are favourable to dispersion • Increase energy efficiency of operations • Adopt operation procedures to reduce the magnitude, frequency and duration of fugitive emissions • Establish well-defined upset notification criteria and actions (OGC Draft Guideline under review)	• **S:** Detailed analysis is not normally required unless frequency and intensity create the potential for significant impacts • **E:** Increase stack height; flare during periods when vegetation is less sensitive to exposures; add supplementary fuel gas; adopt a meteorological or ambient monitoring plan to restrict emissions during undesirable periods • **P:** Use sweet gas for fuel; adopt prudent operation procedures to reduce the magnitude, frequency, and duration of fugitive emissions; adopt low NO_x burners; adopt high sulphur recoveries • **PL:** Use sweet gas for fuel; adopt low NO_x burners

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Significance	• Compare to relevant ambient air quality objectives and deposition criteria • Linkage to human, health, vegetation, and soils disciplines may be required • Risk analysis re: effects below objectives or criteria to be based on cumulative impacts to determine acceptability	• **S:** Detailed analysis not normally required unless frequency and intensity create potential for significant impacts
Follow-up	• Ambient monitoring and associated pre- and post-vegetation monitoring may be required • Record reporting of monitoring results including deposition in cumulative database	• **S:** Detailed analysis is not normally required unless frequency and intensity create the potential for significant impacts • **P:** Conduct source monitoring to confirm that emissions meet design specifications • **PL:** Conduct source monitoring to confirm that emissions meet design specifications

Table F-2. Soils and Terrain

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Surface disturbance of soil • Soil compaction (e.g., along rights-of-way or at facility sites) • Soil erosion (e.g., during road/facility construction or along improperly reclaimed rights-of-way or from use of ATVs) • Degraded soil quality • Impacts on permafrost soils	• **S:** Erosion on steep slopes and along streams; subsidence in permafrost areas; increased ATV access leading to soil erosion • **E:** Contaminant spills; acid/trace element deposition; on- and off-site drainage impacts; Topsoil/organic salvage • **P:** Contaminant spills; acid/trace element deposition; on- and off-site drainage impacts; Topsoil/organic salvage • **PL:** Drainage obstruction, particularly in wetlands; pipeline ruptures/leaks into soil; topsoil/organic salvage
	VECs	• Soils on steep slopes / highly erodible soils • Riparian soils • Permafrost soils • Rare soils • High quality/capability soils; highly productive for agriculture or forestry	• **E:** Acid-sensitive soils • **P:** Acid-sensitive soils
	Spatial Boundaries	• Site-specific, except for potential drainage contamination due to erosion • Link to land use (high capability forest and agricultural areas, access density links to terrain stability)	• **E:** Linkage to Air Quality for acid deposition effects • **P:** Linkage to Air Quality for acid deposition effects
	Temporal Boundaries	• Track/note season, and site conditions during disturbance/ reclamation	• **S:** Periodic and short-term • **E:** For the duration of the disturbance/emissions • **P:** For the duration of the disturbance/emissions • **PL:** Ground disturbance is periodic and short-term; rupture/leak potential exists for the operative life of pipeline
Analysis		• Sum total of VECs lost to development (e.g., use GIS overlay to identify VEC proximity to development, and/or affected extent) • Soil erodibility (e.g., through modelling using topographic and soils data) • Measurement or modelling of sediment loads (e.g., total suspended solids and total dissolved solids, and plume dispersions/overlaps	• **E:** Water quality analysis to quantify erosion impacts (chemical, nutrient, salinity, sedimentary); link with Air Quality on acid deposition model • **P:** Water quality analysis to quantify erosion impacts (chemical, nutrient, salinity, sedimentary); link with Air Quality on acid deposition model

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Mitigation	• During planning and design, avoid areas with sensitive terrain (e.g., slopes with unstable soils), and areas with discontinuous or continuous permafrost • In areas of discontinuous permafrost, it is very important that the overlying vegetation not be disturbed. Thus, reduce disturbances to native vegetation by minimizing the width of the cleared area • Where clearing of vegetation is required, set the blading height above ground level (e.g., 10 to 20 cm) so that root balls and ground covers are left intact • Use low-impact vehicles (e.g., low pressure-tires or wide-pad tracked vehicles) • If soils are disturbed, use temporary erosion control measures (silt fencing, hay bales, soil fabric) to minimize effects, followed by revegetation, where necessary • Seasonal closures may be used to avoid the movement of equipment on soft substrates and sensitive terrain. Where equipment must be moved across sensitive vegetation or terrain, do so when the ground is solidly frozen using low-impact vehicles	**S:** Ensure that cutlines do not run down slope in areas prone to erosion by surface or near-surface drainage
Significance	• There are no current standards or thresholds for soil loss outside of conservation and reclamation guidelines • Balance goals of regional land use plans with extent and location of VECs	• **S:** Dependent on frequency and intensity of seismic work • **E:** Linkage to Air Quality and Vegetation is required for acid deposition • **P:** Linkage to Air Quality and Vegetation is required for acid deposition
Follow-up	• Follow monitoring protocol in project conservation and reclamation plans • Monitor cumulative regional loss of VECs • Continue linkage with Air Quality, Vegetation • Monitor sediment loads in watersheds	• **S:** Not required unless intensity of work creates erosion concern within watersheds, or the extent of disturbance impacts regional productivity • **E:** Conduct periodic regional soil sampling/analysis for changes to nutrient regime and chemical parameters • **P:** Conduct periodic regional soil sampling/analysis for changes to nutrient regime and chemical parameters

Table F-3. Aquatic Ecosystems

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Disposal of treated or untreated wastewater or solid waste (e.g., associated with camp operations) can result in changes to surface water quality. Effects may include transport of fecal coliforms making water unusable downstream, and nutrient enrichment of surface water leading to increased algal production and eutrophication that can degrade fish habitat and reduce fish abundance • Episodic release of toxic effluents or solid waste can result in changes to surface water quality, leading to mortalities of benthic invertebrates, and fish of all age classes • Road access creates potential for spills of truck-transported fluids which can cause fish toxicity in watercourses, and contamination of downstream water supply. Soil erosion and particle transport also occurs from roads and off-road ATV use • Potential disruption of fish passage at stream crossings (perched culverts, velocity barriers, mass wasting, etc.) can occur • Water withdrawal (camp use, hydrostatic testing), or water quality degradation may restrict water use and availability downstream. Water withdrawal may also reduce wetted area of fish habitat and cause isolation of pools • Disturbance of soils can result in the release of sediment to surface water causing anomalous turbidity and limiting water use and suitability downstream. Other effects from increased sediment load include decreased fish survival rates (including decreased spawning success), increased sublethal effects in fish (e.g., gill abrasion, decreased feeding effectiveness), effects of acute turbidity on individual fish, and impacts of sedimentation on incubating eggs, and invertebrate fauna)	• **S:** Temporary or permanent barriers to fish movement due to ice bridges or slash can occur • **E:** Leaching of contaminated fluids from containment pits leading to exfiltration and release of toxic fluids can cause mortalities or abnormalities in benthic invertebrates and fish of all age classes. Other effect include downward migration of contaminated fluids; potential groundwater contamination; mortality of fish due to changes in water quality or altered water flows; and alteration of natural drainage patterns that may disrupt groundwater flows and reduce availability of suitable bull trout spawning habitat • **P:** Episodic and chronic release of toxic fluids to surface water caused by failure of production facilities (e.g., release of glycol, salt water, condensate, lubricants, crude oil, etc.) can cause mortalities or abnormalities of benthic invertebrates and fish of all age classes: other effects include potential reduction in groundwater aquifers and flows; altered surface water flow patterns, changes in channel morphology, or channel locations due to inappropriate lease location leading to changes to rearing and spawning habitat, and restriction of movements • **PL:** Episodic toxic fluid releases, due to pipeline failure, can affect water quality and lead to fish mortality (with resulting impacts to the food web); altered surface water flow patterns, changes in channel morphology, or channel locations (e.g., scouring, channelization) can lead to changes to rearing and spawning habitat, and restriction of movements

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects (cont'd)	• Potential disruption of fish passage at stream crossings (perched culverts, velocity barriers, mass wasting, etc.) can occur • Alteration of natural drainage patterns (in particular, disruption of groundwater flow patterns) may have effects on suitability of bull trout spawning habitat. Altered water flows from facilities construction, water withdrawls, etc. can affect natural drainage patterns • Exploitation of fish by crews/staff during recreation time • Exploitation of fish can increase in previously inaccessible areas. Effects vary with methods employed (i.e., heli-portable/hand-cut versus traditional heavy-machine access). This is primarily an issue for foothill streams where vulnerable congregations of sport-fish occur during ice-free months (i.e., adult grayling over summering habitat and bull trout spawning areas)	
	VECs	• Water quality and quantity for human consumption • Habitat quality for all indigenous fish species (including water quality and quantity) • Bull trout distribution and abundance throughout the MKMA • Arctic grayling distribution and abundance throughout the study area, particularly in the Interior Plateau • Critical habitat areas (i.e., spawning, overwintering) • Intact riparian communities (post-disturbance riparian community is left in such condition to prevent ongoing erosion (i.e., vegetation becoming re-established, etc.)	

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Spatial Bound-aries[1]	• Depending on site characteristics, impacts may be local to regional scale for both sediment transport and wastewater discharges • Water quality effects, and effects due to alternation of habitat are typically local where risk is perceived to be high or site-specific sampling is required as a condition of the permit. Data would be collected from index sites (protected areas) and potentially affected sites • Effects due to water withdrawl are typically local • Effects of alteration of drainage patterns are typically subregional • Effect due to barriers to movement are typically subregional • Effects of access are typically subregional to regional scale depending on facility/access density, but with local emphasis where risk is perceived high (i.e., access in vicinity of critical habitats).	• **E:** Subregional for release or migration of toxic effluent or fluids and wastewater discharges. Local scoping is used to determine significance of effects based on no net loss tolerance in Federal *Fisheries Act* • **P:** Subregional for release or migration of toxic effluent or fluids and wastewater discharges. Local scoping is used to determine significance of effect based on no net loss tolerance in Federal *Fisheries Act* • **PL:** Subregional to regional for release or migration of toxic effluent or fluids (i.e., due to pipeline failure)
	Temporal Bound-aries[2]	• Under normal circumstances, typical sediment transport events are resolved in the short- to medium-terms therefore, look back 10 years within one reach upstream and one reach downstream • Water withdrawal issues and barriers to movement are long-term • Effects of altered hydrology may be long-term • Effects of increased exploitation of fish stocks resulting from access development are long-term, all historical access development within watershed group must be considered • Potential exists for catastrophic, long-term impacts to individual populations (e.g., BT spawning aggregations); recovery time is undetermined)	• **E:** Potential for episodic release of contaminants from facility failure is short-term (for the duration of project) • **P:** Chronic long-term sediment disturbance from permanent production sites; long-term for episodic or chronic toxic fluid release resulting from failure of production facilities (must look at all historical development within the watershed group) • **PL:** Chronic long-term sediment transport from sites that are not stabilized; long-term potential for episodic toxic fluid release for the duration of pipeline use

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[1] Spatial scales defined as: **Local** immediate area of activity i.e., RoW, lease, workspace, or camp facilities) on a reach or sub-drainage scale. Layout would include upstream to downstream comparisons before, during, and after disturbance; **Subregional**: within a watershed group or multiple groups (if disturbance is near the d/s boundary of a group, then adjacent group will need to be considered); and **Regional:** ecoregion, as defined for terrestrial systems (Demarchi 1995) or aquatic systems (Perrin and Blyth 1998)

[2]. Temporal boundaries for aquatic ecosystems defined as: **short-term:** less than 1 year; **medium-term:** 1-10 years; and **long-term:** greater than 10 years

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Analysis	• Cannot assess significance of an effect on a fish population without background information on the population • For surface water, measurement or modelling of sediment loads (e.g., total suspended solids and total dissolved solids, and plume dispersions/overlaps • For water quality and fish habitat issues, apply stressor thresholds to determine potential effects. Thresholds may be density of seismic lines, roads, drilling locations, production facilities, percent riparian area cleared, average stream crossing frequency, etc • Map threshold density values to identify hot spots or a graded scale of categories showing potential risk of effect (high density means increased risk). Lay seismic density data on terrain stability data to determine potential areas of risk) • Develop a reference map coded with broad categories of fish habitat quality for VEC species to be used as a baseline to determine the risk of site disturbance • Sampling to be co-ordinated under a cumulative effects design, including reference sites in protected areas. This process is required to build a water quality database that is virtually non-existent for the study area at present. Data can be used in regional water quality models • Criteria that determine critical reaches or bodies of water need to be determined from local data (e.g., inventory, radio telemetry studies) and indigenous knowledge. These criteria can be upgraded over time with any index site and impact site sampling that would be required as a condition of operating permits	• **E:** For water withdrawal effects, calculate estimated consumption rates per rig site extrapolated to rig site density; groundwater information and modelling tools will be required to determine the potential dispersion zone from the drilling program, and the potential for overlap with other similar effects • **PL:** For water withdrawal effects calculate estimated consumption rate (hydrostatic testing) extrapolated to site density

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Mitigation	- Schedule and complete construction activities in existing instream work windows - Access management - avoid development of permanent access, manage temporary access through use of gated roads, reclaim temporary access upon project completion - Use existing linear openings and encourage use of shared linear corridors and workspaces - Maintain riparian buffers - Bank armouring - Reclaim temporary access upon project completion - Undertake stream habitat restoration initiatives, where applicable	- **S:** Coordinate seismic programs (i.e., use of shared access and existing linear corridors); maximize use of heli-portable and hand-cut line seismic methods - **E:** Heli-portable exploration drilling; horizontal directional drilling (HDD) or horizontal punch or bore methods to minimize streambank disturbance; use of non-toxic additives; use of diversion ditches - **P:** Stabilize and revegetate riparian areas; liquid waste to be removed or treated before discharge - **PL:** Employ best-practices stream crossing methods to minimize erosion and allow unimpeded fish access; encourage installation of pipe diameter in excess of current capacity requirements; use of horizontal directional drilling (HDD) or horizontal punch or bore methods to minimize streambank disturbance.
Significance	- Follow regulatory guidelines (e.g., Canadian Council of Ministers of Environment guidelines, *Forest and Range Practices Act*, *Federal Fisheries Act)*, and thresholds based on evidence in the primary literature	
Follow-up	- Benthic invertebrate and fish sampling for minimum of one growing season after completion of clean-up/recovery or failure event (not applicable for seismic) - Develop a comprehensive regional water quality monitoring program. Companies operating in areas where there is potential risk of effects can co-operatively fund a program that contributes to a central water quality database from which a regional scale CEA could be done.	- **S:** Index of seismic sites.

Table F-4. Vegetation

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Direct immediate loss of vegetation (structure, function and composition) due to clearing • Fragmentation (spp. alienation and reduced distribution) of large patches of vegetation due to clearing • Altered species composition and successional stage of plant communities due to clearing • Altered species composition and vigour of wetland plant communities due to hydrological changes resulting from vegetation clearing • Altered ratio and distribution of uplands and wetlands due to vegetation clearing	• **E:** Changes in health and species composition of plant communities due to air emissions from construction activities, well test flaring, and service vehicles and equipment; direct physical effects and indirect chemical effects on vegetation due to road dust and road salt • **P:** Changes in health and species composition of plant communities due to air emissions from construction activities, well test flaring, and service vehicles and equipment; direct physical effects and indirect chemical effects on vegetation due to road dust and road salt
	VECs	• Plant Species at Risk (provincially, federally) • Plant species or communities that are significantly abundant regionally, provincially, or federally • Plant species or communities of socio-economic importance (e.g., First Nations traditional use) • Plant species or communities that are components of rare or sensitive ecosystems, or that are highly susceptible to disturbance	
	Spatial Boundaries	• For each VEC, select spatial scales at the site-specific level by using distributions of plant species and communities, and location and extent of disturbances	
	Temporal Boundaries	• For riparian plant communities, temporal boundaries will vary with site-specific conditions and extent of restoration efforts • For rare ecosystems, temporal boundaries will vary with ecosystem type and extent of restoration efforts • Impacts to sensitive vegetation such as old-growth forests, riparian plant communities and rare ecosystems will be typically long-term in durations. For example, for old-growth forests, the temporal boundary should be at least 120 years past the decommissioning phase	• **S:** Because areas cleared along seismic lines are not reclaimed, and generally, are kept open by recreational users, impacts are expected to be permanent • **E:** Air emissions and chemical toxins are expected to affect plant health of all VECs from at least 0-life of development activity; however, residual effects could last much longer • **P:** Air emissions and chemical toxins are expected to affect plant health of all VECs from at least 0-life of development activity; however, residual effects could last much longer • **PL:** Pipelines are generally buried, and are allowed to revegetate naturally following abandonment

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Analysis	For measuring cumulative effects on a project-specific basis, develop measures based on site-specific information such as TEM and baseline inventories of plant species and communities, which could include measurement of: • Changes in area of vegetation types or communities (e.g., ha vegetation cleared for different communities) • Changes in juxtaposition of vegetation communities (Note: this is a component of fragmentation) • Changes in integrity of single plant communities (Note: this is a component of fragmentation) • Changes in vegetation community composition • Changes in plant species' relative or absolute abundance • Changes in plant species' distribution	
Mitigation	• Avoid sites with uncommon or sensitive plant communities • Limit extent of vegetation clearing • Avoid fragmenting large patches of vegetation • Co-ordinate seismic line or access road development among tenure holders • Where new road access must be created, minimize the length of the new road that is required and, where possible, control public access to the road • Develop progressive rehabilitation plans based on direction from MK Act and land use planning zones	• **S:** Avoid starting seismic lines along an existing right-of-way or road. Use hand-cutting for the first 50 to 100 m to maintain a buffer of natural vegetation (this will prevent easy access by ATVs and other vehicles to the right-of-way) • **E:** Drill multiple wells from single pad where possible (i.e., directional drilling) • **PL:** Re-vegetate major access points
Significance	• Refer to existing standards such as the results-based code of the *Forest and Range Practices Act* • For rare plants or unusual plant communities, a loss of more than 5 to 10 percent of the regional population would likely be considered unacceptable • Identify appropriate thresholds for vegetation, e.g., maximum density of linear and block disturbances km^2, Minimum retention of each vegetation community to prevent extirpation of vegetation units (i.e., plant species or communities) and loss of vegetation types	

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Follow-up	• Establish pilot study areas and monitor plant species and community changes over time, e.g., monitoring ecosystem effects on old-growth, riparian, and rare systems/species • Create benchmark monitoring areas to assess vegetation recovery rates from disturbances • Undertake sensitive ecosystem inventories and mapping to monitor changes in plant species and communities over time (e.g., BEC-site series mapping at the operational scale)	

Table F-5. Wildlife

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Direct habitat loss due to vegetation clearing • Habitat fragmentation and alienation due to vegetation clearing • Mortality due to increased human and predator access • Disruption of wildlife movements due to vegetation clearing and increased human and predator access • Sensory disturbance due to construction/camps (i.e., greater levels of human activity and noise that can cause some wildlife species to avoid the area) • Problem wildlife incidents at camp sites	• **E**: Sensory disturbance from drilling activities • **P**: Sensory disturbance from plants and processing sites
	VECs	• Species at Risk (provincially, federally) (e.g., grizzly bear) • Species or populations which are significantly abundant regionally, provincially, or federally (e.g., ungulates) • Species or populations of socio-economic importance (e.g., First Nations traditional use, species that are hunted/ trapped such as moose and marten) • Species that are dependent on rare or sensitive ecosystems (e.g., warblers are dependent on boreal forests during the migratory period)	
	Spatial Boundaries	• For each VEC, select spatial scales at the site-specific level by using species home ranges and territory sizes, habitat availability, and suitable buffers	
	Temporal Boundaries	• Boundaries will be dependent upon the specific issues and the individual habitat requirements of each VEC. For example, sensory disturbance and increased mortality due to construction activities will be reduced when the construction period ends (i.e., short-term). Conversely, impacts to habitat may be long-term. For example, for fisher and marten, which generally require old-growth forest habitats, impacts may last over 100 years (i.e., the time it takes old-growth forests to recover)	

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Analysis	For measuring cumulative effects on a project-specific basis, develop measures based on site-specific information such as TEM and baseline inventories of local populations, which may include measures such as • Species-specific habitat modeling (e.g., changes in availability of habitat types over time; changes in availability of core security habitat over time) • Changes in species' relative or absolute abundance over time • Changes in mortality rates over time • Changes in fur returns over time • Changes in cow:calf ratios over time • Seismic line density; road and trail density; distance of seismic lines, roads, and trails from towns (regarding access issues) • Location of logging, hunting, and recreational camps; location of guide-outfitter territories (regarding access issues) • Road, seismic line, and pipeline location relative to wildlife movement corridors • Buffer zones around different developments can be identified to measure areas of sensory disturbance and avoidance by wildlife	
Mitigation	• Coordinate planning efforts with other industries to minimize the size and number of areas cleared (e.g., for access) • Reclaim areas cleared for seismic lines as soon as possible • Close roads once activity has been completed • Minimize disturbances (e.g., hunting, harassment) to wildlife from work crews • Use pre-development field surveys to locate the best placement of facilities so sensitive habitats are avoided	• **S:** Use existing utility corridors wherever possible; close rights-of-way once seismic activity has been completed • **PL:** Use existing utility corridors wherever possible; close rights-of-way following abandonment

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)

Significance	• Refer to guidelines and objectives in regional land/resource use plans and regional wildlife management plans
	• Refer to existing standards and guidelines (e.g., the results-based code of the *Forest and Range Practices Act*, the BC Identified Wildlife Management Guidelines, Boreal Caribou Committee Industrial Guidelines)
	• Identify appropriate thresholds for wildlife. For example:
	  • Wildlife Abundance
	  • Minimum cow:calf ratio
	  • Minimum number of individuals per km^2
	  • Habitat Loss/ Fragmentation
	  • Minimum habitat effectiveness (%)
	  • Minimum core security habitat area
	  • Minimum area of contiguous habitat
	  • Maximum number of vehicles per day
	  • Maximum number of backcountry visitors per day
	  • Maximum density of linear disturbance per km^2
	  • Wildlife Mortality
	  • Maximum loss of females per year (number per 100 females)
	  • Wildlife Movements
	  • Minimum area of contiguous habitat
	  • Maximum number of vehicles per day
	  • Maximum number of backcountry visitors per day
	  • Maximum density of linear disturbance per km^2	

Follow-up	• Monitor key wildlife species population changes over time by conducting on-going inventories • Monitor areas and patterns of losses and changes in habitat types over time using air photo coverage and TEM • Monitor rates of wildlife mortality by collecting and analyzing statistics on roadkills, problem wildlife incidences, and hunting and trapping returns • Collect data on wildlife movements by conducting on-going radio telemetry studies; use this information to monitor changes in wildlife movements due to sensory disturbances from development projects	

Table F-6. Land and Resourse Use

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Visual impacts • Decrease in wilderness solitude experience and loss of sustainable economic opportunities dependant on wilderness (e.g., ecotourism) • Other industrial users may be affected by temporary or permanent loss of resources (e.g., timber or agricultural land) • Indirect impacts to wildlife or fish, if significant, could impair hunting, trapping or fishing success in the region	• **S:** Creation of new access is the primary issue • **E:** May result in disturbances to other resource users by way of noise, dust, odours, visual impacts, loss of areas of use, or the creation of new access • **P:** May result in disturbances to other resource users by way of noise, dust, odours, visual impacts, loss of areas of use, or the creation of new access. There may also be a permanent loss of lands for other uses • **PL:** Creation of new access along rights of way; disturbance to patterns of use of trappers or guide outfitters; and loss of timber or other resource use capability along the right of way
	VECs	• Wilderness Quality (important in region for recreation and supports economic activity, e.g., tourism, guide outfitting) • Wilderness Access (important in region and supports economic activity, e.g., tourism, guide outfitting) • Industrial Access (important to support region's resource-based economy) • Alternate Economic Opportunities (e.g., Ecotourism) (important in promoting diversified economic activity) • Viewscapes (important in maintaining wilderness values)	

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Spatial Boundaries	• Recreation access: estimate the distance on either side of a right-of-way/seismic line that users might likely travel (i.e., determine the user footprint). This distance could then be used to buffer the right-of-way and create polygons of access representing a spatial boundary • Recreation experience: in some cases spatial boundaries have been determined using noise, dust or odour plumes (most applicable for impacts resulting from construction phase) • Visual quality: models of visual impacts (i.e., viewshed analyses) can be used to determine the geography extent of visual impacts • Land clearing (e.g., availability of harvestable timber): may be appropriate to use management units as spatial boundaries (e.g., Timber Supply Areas) • Hunting, trapping and fishing uses: use spatial boundaries that have been set for harvested species (e.g., watersheds for fisheries) or management/ administrative boundaries such as wildlife management units or trapper/outfitter territories	• **PL:** Pipelines are often used as transportation corridors by land users. For VECs that relate to access, spatial boundaries could be determined by following access off the pipeline until contact is made with a public road, which the project has no control over access
	Temporal Boundaries	• For all types of activities, for land and resource use impacts, the life of the project is typically used as a temporal boundary, after which time lands can be reverted to their pre-project use (assuming access will be removed)	**S:** Life of seismic line as it exists for non-industrial resource users (i.e., until it is not longer usable as a right-of-way) is an appropriate temporal boundary
Analysis		• Existing land use plans provide a tool for determining whether current or projected uses are consistent with land use objectives • Calculate the amount of land lost to other uses, e.g., determine loss of merchantable timber or high quality arable land • Use scenario development forecasting to show incremental losses of land for other purposes or use remotely sensed data to show changes in landscape over time • Information from visitor use studies could be use to qualitatively/ quantitatively discuss loss of or satisfaction with present wilderness recreation opportunities • Model incidental access that may be created by a new access corridor • Use air quality or noise plume modeling, or viewshed modeling, to show extent of impacts	**S:** Road density analysis: calculate the total km (or km per area) of access created by seismic lines **PL:** Road density analysis: calculate the total km (or km per area) of access created by pipelines

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Mitigation	• Notify other land users of activities to avoid conflicts • Minimize noise and air quality impacts through project scheduling and enforcement of standards for noise, dust, emissions, etc • Minimize disturbances to existing access through project scheduling and provision of alternative routes • Minimize impacts of crews on resources (e.g., hunting and fishing) through proponent-enforced restrictions • Minimize visual impacts and impacts to other resource users by limiting total clearing as much as possible • Coordinate industrial access to minimize changes to existing land use patterns	**S:** Close rights-of-way once seismic activities completed through roll-back and other techniques **PL:** Close rights-of-way when no longer needed for pipeline operations, through roll-back and other techniques
Significance	• Refer to LRMPs or lower-level plan objectives for land use and identify cumulative impacts that may not be consistent with these objectives • Some standards exist for visual quality (i.e., Visual Quality Objectives for forestry). May also be site-specific guidelines for access (e.g., in the MKMA), hunting, trapping, or fishing • Significance may also be measured in terms public acceptance of impacts, permanent versus reversible impacts, and impacts that cannot be compensated • Some work has been done on determining thresholds for km of new access (needs further investigating) • Measures of Limits of Acceptable Change (LAC) may be derived with public input • In some high-value recreation areas, the Recreation Opportunity Spectrum may be used to identify desirable conditions	
Follow-up	• Monitor specific impacts, e.g., changes to hunting success that may be attributed to the project • Review past and projected changes to land use patterns over time to estimate rate of change in the region • Monitoring of land use on a regional scale must involve many different agencies that manage land and resource use activities	

Table F-7. First Nations

Assessment Process		Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Scoping	Effects	• Wildlife and wildlife habitat • Water quality • Fish and fish habitat • Affect on traditional lifestyles and values, cultural/spiritual sites and values • Traditional and contemporary use i.e., access to hunting, harvesting, and trapping areas • Increased harvesting pressures • Botanical resources and other sustenance resources • Fragmentation of habitat, and increased roads	
	VECs	• Use indigenous knowledge, Traditional Use Studies, or community land and resource plans (when available) to identify key values such as important harvested plants and wildlife species, or culturally/spiritually significant sites	
	Spatial Boundaries	• For First Nations VECs, boundaries should be determined through consultation with First Nations and ideally incorporate indigenous knowledge	
	Temporal Boundaries	• For First Nations VECs, boundaries should be determined through consultation with First Nations and ideally incorporate indigenous knowledge	
Analysis		• Involvement of First Nations in baseline inventory and research studies • Use of Traditional knowledge, Traditional Use Studies, and other First Nation community-based management plans (when available), which could be obtained through information sharing agreements • Ecological land classification	
Mitigation		• For First Nations VECs, boundaries should be determined through consultation with First Nations and ideally incorporate indigenous knowledge	

Assessment Process	Generic to All Project Types	Specific to Certain Project Types (S = seismic; E = exploration; P = production; PL = pipeline)
Significance	• For First Nations VECs, boundaries should be determined through consultation with First Nations and ideally incorporate indigenous knowledge	
Follow-up	• For First Nations VECs, boundaries should be determined through consultation with First Nations and ideally incorporate indigenous knowledge	

Appendix G: OGC Application Cumulative Effects Screener (ACES)

Appendix G is organized into the following three parts:

- Part 1: Routine Screener
- Part 2: Expanded Review
- Part 3: Pilot Implementation

Parts 1 and 2 begin with a 'Users Guide' or annotated version (i.e., provides an explanation of how to complete the forms) followed by the actual form that can directly be used by the OGC (this is simply the same form that appeared before, but without all the explanatory notes).

Part 3 outlines a pilot implementation process that the OGC may use to test the proposed ACES.

For convenience, Figure 4-4 has been reproduced on the next page (as Figure G-1) to assist interpretation of the information provided in Parts 1 and 2 of this appendix.

Figure G-1: OGC Application Cumulative Effects Screener (ACES)

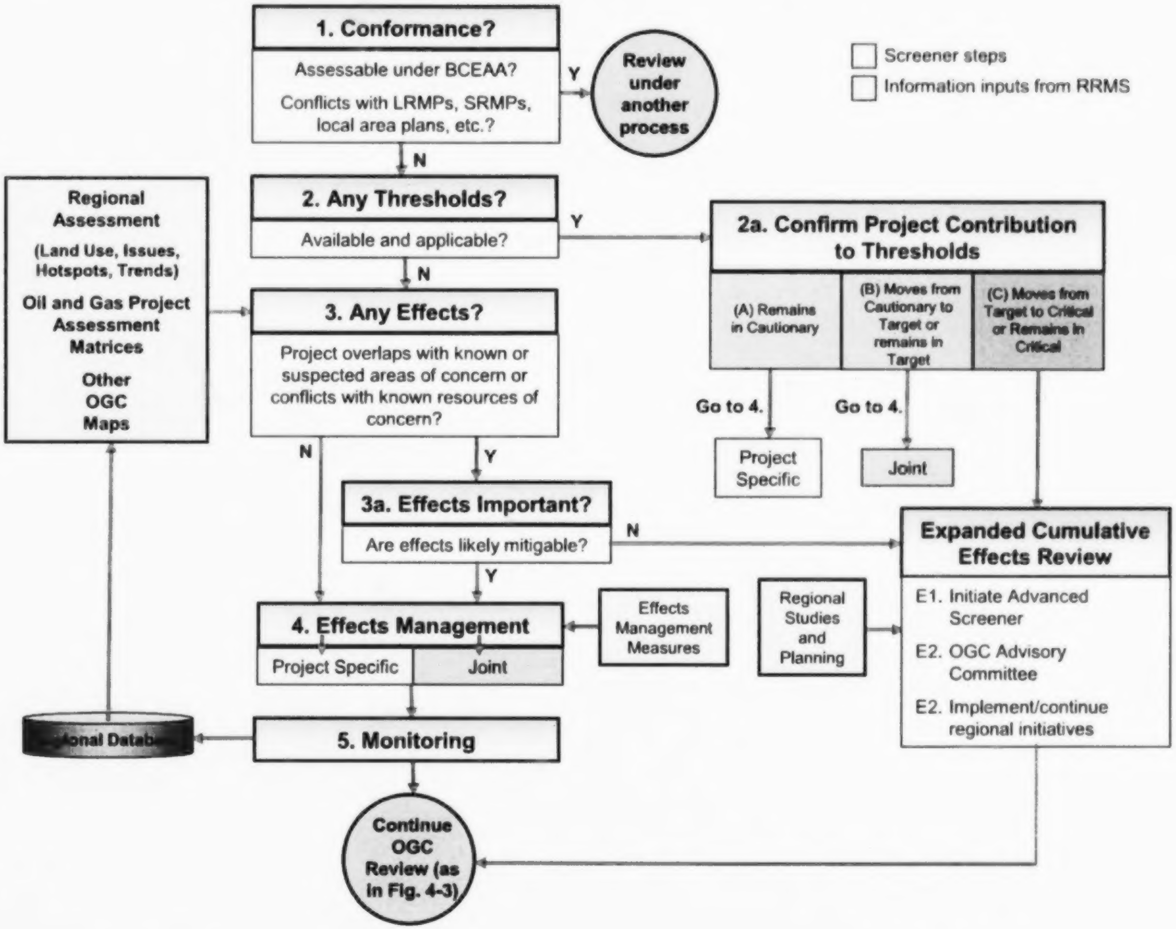
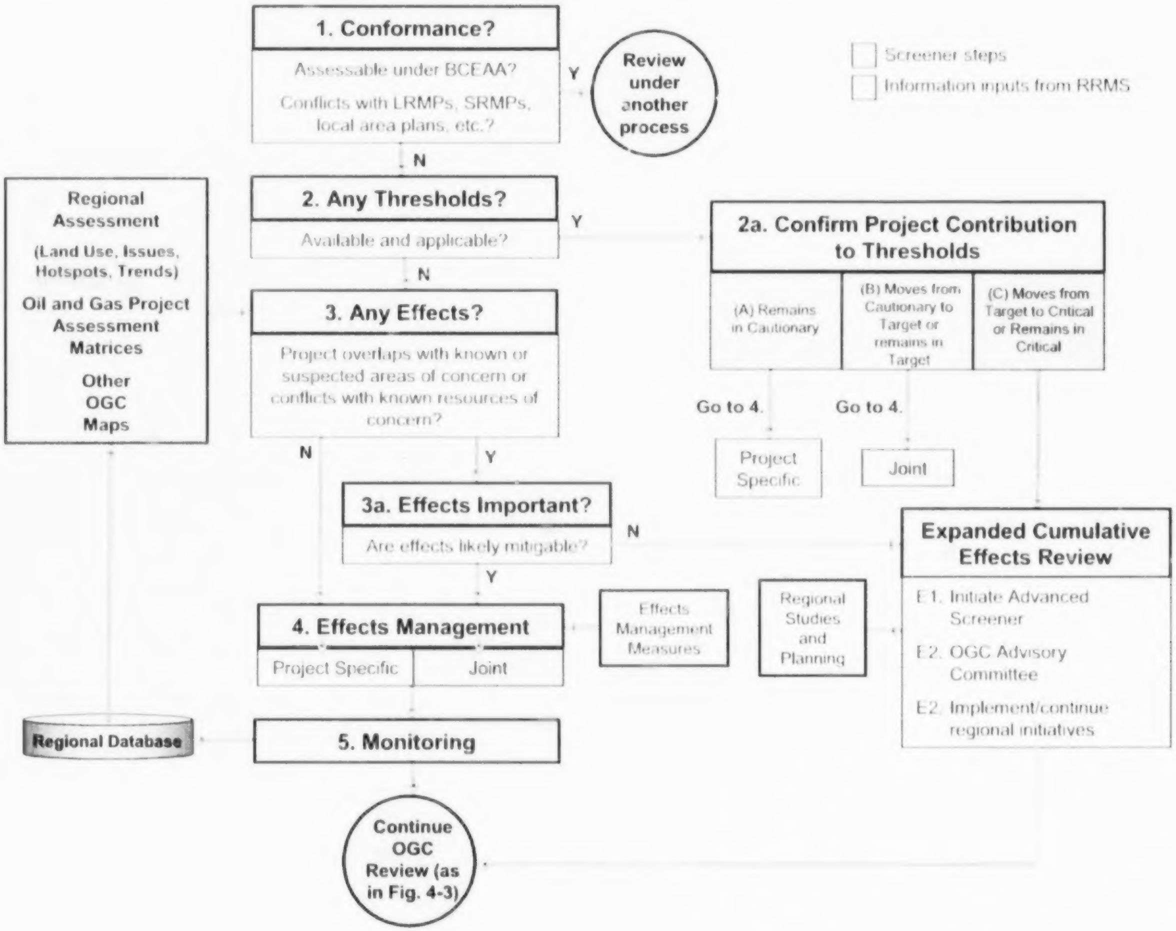

1. Conformance?
Assessable under BCEAA?
Conflicts with LRMPs, SRMPs, local area plans, etc.?
Y
Review under another process
N
Screener steps
Information inputs from RRMS
Regional Assessment
(Land Use, Issues, Hotspots, Trends)
Oil and Gas Project Assessment Matrices
Other OGC Maps
2. Any Thresholds?
Available and applicable?
Y
2a. Confirm Project Contribution to Thresholds
(A) Remains in Cautionary
(B) Moves from Cautionary to Target or remains in Target
(C) Moves from Target to Critical or Remains in Critical
Go to 4.
Project Specific
Go to 4.
Joint
N
3. Any Effects?
Project overlaps with known or suspected areas of concern or conflicts with known resources of concern?
N
Y
3a. Effects Important?
Are effects likely mitigable?
N
Expanded Cumulative Effects Review
E1. Initiate Advanced Screener
E2. OGC Advisory Committee
E2. Implement/continue regional initiatives
Y
4. Effects Management
Project Specific
Joint
Effects Management Measures
Regional Studies and Planning
onal Datab
5. Monitoring
Continue OGC Review (as in Fig. 4-3)

Figure G-1: OGC Application Cumulative Effects Screener (ACES)


1. Conformance?
Assessable under BCEAA?
Conflicts with LRMPs, SRMPs, local area plans, etc.?
Y
Review under another process
Screener steps
Information inputs from RRMS
N
2. Any Thresholds?
Available and applicable?
Y
2a. Confirm Project Contribution to Thresholds
(A) Remains in Cautionary
(B) Moves from Cautionary to Target or remains in Target
(C) Moves from Target to Critical or Remains in Critical
Go to 4.
Go to 4.
Project Specific
Joint
Regional Assessment
(Land Use, Issues, Hotspots, Trends)
Oil and Gas Project Assessment Matrices
Other OGC Maps
N
3. Any Effects?
Project overlaps with known or suspected areas of concern or conflicts with known resources of concern?
N
Y
3a. Effects Important?
Are effects likely mitigable?
N
Y
Expanded Cumulative Effects Review
E1. Initiate Advanced Screener
E2. OGC Advisory Committee
E2. Implement/continue regional initiatives
4. Effects Management
Project Specific
Joint
Effects Management Measures
Regional Studies and Planning
Regional Database
5. Monitoring
Continue OGC Review (as in Fig. 4-3)

Part 1: Routine Screener

Users Guide

Note the following:

1. *An answer of "yes" [Y] or "no" [N] is written into each box in the rightmost column.*
2. *The table provides a version appropriate for understanding the screening process, providing decision criteria and examples of sources of information.*
3. *The table does not provide space to record items contributing to the decisions (e.g., data sources actually used, assumptions, comments, mitigation measures required). The tables can however be expanded to include such space to meet OGC requirements for an audit trail or record of the screening.*

OGC Routine Screener

Project Information

Project Title:

Proponent:

Location:

File #:

1. Conformance?

Is the project assessable under the *BC Environmental Assessment Act* (BCEAA)? ☐

Does the type of project and its location conflict with applicable land use plans? ☐

If yes to either question, refer the application to another appropriate review process

Decision criteria: A conflict occurs when it is clear that the project is unacceptable based on unconditional exclusion of such activities.

Information sources: Examples of plans include Land and Resource Management Plans (LRMPs), Sustainable Resource Management Plans (SRMPs), and local area plans (e.g., recreation, wildlife).

2. Any Thresholds?

Are thresholds available and applicable to this project? ☐

If no, go to Step 3

If yes, go to Step 2a

Decision criteria: Thresholds are applied if the OGC has indicated as such for specific geographic areas.

Information sources: Information on thresholds would be available following the completion of a thresholds implementation plan and acceptance to proceed with such thresholds as part of the OGC's regulatory review process.

2a. Confirm Project Contribution to Thresholds

Based on the threshold calculations prepared by the project proponent and submitted to the OGC with their application, which of the following is true based on the project contribution within its applicable designated threshold region (only one of these conclusions is possible for an application)?

(A) project would not change an existing "cautionary" threshold level for region ☐

If yes, go to step 4, single mandate [effects management]

(B) project would move region from "cautionary" to "target" or would not change an existing threshold of "target" in region ☐

If yes, go to step 4, joint [effects management]

(C) project would move region from "target" to "critical" or would occur in a region already at the "critical" threshold ☐

If yes, go to Expanded Cumulative Effects Review

Information sources: When thresholds are implemented, the OGC will have to develop appropriate notification and instruction to applicants (i.e., define new information requirements). A current description in detail indicating the technical aspects of such requirements is provided in Volume 2.

3. Any Effects?

Does the project overlap any known or suspected areas of concern? ☐

Decision criteria: An overlap occurs when the project footprint (as submitted by the proponent) physically resides in the area of concern (i.e., there is a spatial overlap). An area of concern is any pre-defined geographic area associated with an environmental feature of importance (e.g., as established by government notices); and, the project has a reasonable likelihood of affecting that feature given the project's location and type. The question is answered "yes" if the project has a reasonable likelihood of affecting that area given the project's location and type; and, that area is of management concern to government authorities responsible for its management.

Information sources: Potential areas of concern may be obtained and identified from hotspot maps (Appendix H), other map products (e.g., from GOAT, such as fisheries and wildlife mapping), and any published government notices (e.g., Guidelines, Information Letters).

Does the project conflict with known resources of concern? ☐

If yes to either question, go to Step 3a

If no to either question, go to Step 4.

Decision criteria: A resource of concern is any environmental feature as described above; however, one that is not necessarily correlated to any specific pre-designated area? For mobile resources (e.g., wildlife), such conflict is more likely if the project occurs at the same time as the resource occurs in the vicinity of the project (i.e., there is a temporal overlap). The question is answered "yes" if the project has a reasonable likelihood of affecting that feature given the project's location and type; and, that feature is of management concern to government authorities responsible for management of that resource. The likelihood of cumulative effects is therefore greater for a conclusion of "yes" as opposed to "no".

Information sources: The Oil and Gas Project Assessment Matrices (Appendix F) may assist in identifying likely spatial and temporal boundaries.

3a. Effects Important?

Are the project's effects likely mitigable? ☐

If yes, go to step 4.

If no, go to Expanded Review

4. Effects Management

As conditions of application approval, implement project-specific EMMs if:

no in step 3, or ☐

had conclusion (A) in step 2a ☐

As conditions of application approval, implement joint EMMs if:

yes in step 3a, or ☐

had conclusion (B) in step 2a ☐

Information sources: Information on effects management options are provided in Section 4.5 and from the OGC's own list of mandatory and voluntary options. EMMs for the application should be itemized.

5. Monitoring

As conditions of application approval, implement appropriate monitoring measures. ☐

Information sources: Information on monitoring is provided in Section 4.7.2.3 and from the OGC's list of mandatory and voluntary options. Data on project is submitted to regional database. Monitoring measures for the application should be itemized.

Screening Summary

Is the application:

1. Referred to another review process (from step 1)? ☐

2. For an area where thresholds apply (from step 2)? ☐

3. Responsible for moving region to a higher threshold level (from step 2a)? ☐

4. Subject to unique project-specific EMMs? ☐

5. Subject to joint EMMs? ☐

6. Sent to Expanded Review? ☐

If "yes" to (1), identify alternate review process

If "yes" to (4) or (5), proceed with recommendation to approve subject to results of referral process

If "yes" to (6), proceed with referral process but subject to conditions of expanded review

Routine Screener Form

The next page (front and back) provides the form for the routine screener.

OGC Routine Screener

Project Information

Project Title:

Proponent:

Location:

File #:

1. Conformance?

Is the project assessable under the *BC Environmental Assessment Act* (BCEAA)? ☐

Does the type of project and its location conflict with applicable land use plans? ☐

If yes to either question, refer the application to another appropriate review process.

2. Any Thresholds?

Are thresholds available and applicable to this project? ☐

If no, go to Step 3

If yes, go to Step 2a

2a. Confirm Project Contribution to Thresholds

Based on the threshold calculations prepared by the project proponent and submitted to the OGC with their application, which of the following is true based on the project contribution within its applicable designated threshold region (only one of these conclusions is possible for an application)?

(A) project would not change an existing "cautionary" threshold level for region ☐

If yes, go to step 4, project-specific [effects management]

(B) project would move region from "cautionary" to "target" or would not change an existing threshold of "target" in region ☐

If yes, go to step 4, joint [effects management]

(C) project would move region from "target" to "critical" or would occur in a region already at the "critical" threshold ☐

If yes, go to Expanded Cumulative Effects Review

3. Any Effects?

Does the project overlap any known or suspected areas of concern? ☐

Does the project conflict with known resources of concern? ☐

If yes to either question, go to Step 3a.

If no to either question, go to Step 4.

3a. Effects Important?

Are the project's effects likely mitigable? ☐

If yes, go to step 4.

If no, go to Expanded Cumulative Effects Review

4. Effects Management

As conditions of application approval, implement project-specific EMMs if:

no in step 3; or ☐

had conclusion (A) in step 2a ☐

As conditions of application approval, implement joint EMMs if:

yes in step 3a; or ☐

had conclusion (B) in step 2a ☐

5. Monitoring

As conditions of application approval, implement appropriate monitoring measures. ☐

Screening Summary

Is the application: ☐

1. Referred to another review process (from step 1)? ☐

2. For an area where thresholds apply (from step 2)? ☐

3. Responsible for moving region to a higher threshold level (from step 2a)? ☐

4. Subject to unique project-specific EMMs? ☐

5. Subject to joint EMMs? ☐

6. Sent to Expanded Review? ☐

If "yes" to (1), identify alternate review process

If "yes" to (4) or (5), proceed with recommendation to approve subject to results of referral process

If "yes" to (6), proceed with referral process but subject to conditions of expanded review

Part 2: Expanded Review

Users Guide

Note the following:
Check (✓) each box in the rightmost column as verification that the action was done.

OGC Expanded Review

Project Information

Project Title:

Proponent:

Location:

File #:

E1: Advanced Screener

1. Project Effects

Identify effects caused by project ☐

Definition: An effect is a response by the environment to the project.

Decision criteria: Identify effects based on the type of the project and the surrounding environmental conditions.

Information sources: Refer to the Oil and Gas Project Assessment Matrices (Appendix F) for examples of effects.

Identify likely zones of influence for effects ☐

Definition: A zone of influence (ZOI) is the spatial extent of an effect.

Decision criteria: Identify a likely maximum ZOI based on experience and knowledge of effects for the type of project and receiving environment.

Information sources: Refer to the Oil and Gas Project Assessment Matrices (Appendix F) for examples of ZOI.

2. Valued Components

Identify Valued Components (VCs) affected by project ☐

Definition: A Valued Component is an environmental or human feature of importance that could be affected by the project.

Decision criteria: Select only those VCs that are most likely to be affected and for which an effect would be of management concern (i.e., regarding the management of that resource) or of concern to people relying on that resource.

Information sources: Refer to the Oil and Gas Project Assessment Matrices (Appendix F) for examples of VCs.

3. Cumulative Effects

Identify other human actions that may overlap with the project ☐

Definition: An "action" is any project or activity not associated with the project under review.

Decision criteria: For each VC, identify actions that lie within the ZOI for each effect and that also affect the same VCs.

Information sources: Any map sources.

Determine if there are any cumulative effects ☐

Definition: An effect on a VC is cumulative when that VC is affected by more than one human action.

Decision criteria: Itemize each effect and the VC affected for which an overlap occurs.

Information sources: Any sources as described above.

4. Effects Management Measures

Identify appropriate project-specific and joint EMMs ☐

Definition: An effects management measure (EMM) is any initiative to reduce or eliminate an effect.

Decision criteria: First identify mandatory EMMs, then any additional EMMs that likely would be effective in managing the effect while remaining reasonable regarding the degree of responsibility for their implementation by the proponent.

Information sources: Refer to the Oil and Gas Project Assessment Matrices (Appendix F) for examples of EMMs and to Section 4.5 for descriptions of selected EMMs.

5. Residual Effect

Estimate the likely residual effect on each VC ☐

Definition: A residual effect is the state of an effect after the application of EMMs.

Decision criteria: Estimate based on experience of effects from the type of project, receiving environment, and degree of success of the EMMs. The likely trend of a VC is also considered, which is described by the likely direction of an effect (positive, negative or neutral) and the likely duration of the effect's recovery.

Information sources: Experience and knowledge of OGC staff and referrals.

6. Significance of Effects

Evaluate the significance of the project's contribution to cumulative effects ☐

Evaluate the significance of the overall cumulative effects ☐

Definition: Significance is a measure of the importance of an effect. The project's contribution to cumulative effects is the project-specific effect on each VC. The overall project effect is the effect from the project *and* from all other identified actions that affect a VC.

Information sources: Use Tables 1 and 2 to assist in evaluating significance.

E2: OGC Advisory Committee

Refer the project the OGC Advisory Committee ☐

Information sources: See Section 4.2.3.5 for the role of the Committee.

E3: Regional Initiatives

Identify appropriate regional initiatives ☐

Decision criteria: Identify initiatives (regional planning and research studies) that may contribute to a better understanding of the project's effects and/or of the surrounding environment. Such initiatives are typically supported, coordinated and implemented on a regional basis by government or industry and government coalitions.

Information sources: Refer to Section 4.4 for a description of such initiatives.

Evaluating Significance (for Step 6)

Table 1 Criteria for Evaluating Class of Significance

Magnitude of Effect on VC	Trend of VC	
	Positive	Negative or Neutral
Low	Class 1	Class 1
Moderate	Class 1	Class 2
High	Class 2	Class 3

Table 2 Criteria for Evaluating Significance

Project Specific Class on a VC	Overall Class on a VC		
	Low	Moderate	High
Low			
Moderate		░	▓
High	░	▓	▓

To use the tables to evaluate significance:

1. Using Table 1, select the appropriate magnitude of an effect of the project. Magnitude is a measure of the severity of an adverse effect.
2. Using Table 1, select the appropriate trend of the likely future state of the VC. Positive means the state of the VC is likely improving, negative means it is likely worsening, and neutral means it is likely unchanged.
3. Using Table 1, identify the class of effect given the selected magnitude and trend. This is the project-specific class of effect.
4. Repeat steps 1 to 3 for overall class. Overall class is based on the cumulative effect of all human actions on the VC by that effect, including the effects of the project under review.
5. Repeat steps 1 to 4 for any other effects on the VC.
6. Using Table 2 as a guide (i.e., not necessarily definitive), identify the likely significance of each effect given the combination of project-specific and overall class as follows (ensure that any conclusion can be defended):
    - Green combinations are unlikely to be significant for project under review.
    - Amber combinations may be significant for project under review.
    - Red combinations likely to be significant for project under review.
7. Repeat steps 1 to 6 for each other VC affected by the project under review.

Expanded Review Form

The next page (front and back) provides the form for the expanded review.

OGC Expanded Review

Project Information

Project Title:

Proponent:

Location:

File #:

E1: Advanced Screener

1. Project Effects

Identify effects caused by project ☐

Identify likely zones of influence for effects ☐

2. Valued Components

Identify Valued Components (VCs) affected by project ☐

3. Cumulative Effects

Identify other human actions that may overlap with the project ☐

Determine if there are any cumulative effects ☐

4. Effects Management Measures

Identify appropriate project-specific and joint EMMs ☐

5. Residual Effect

Estimate the likely residual effect on each VC ☐

6. Significance of Effects

Evaluate the significance of the project's contribution to cumulative effects ☐

Evaluate the significance of the overall cumulative effects ☐

E2: OGC Advisory Committee

Refer the project the OGC Advisory Committee ☐

E3: Regional Initiatives

Identify appropriate regional initiatives ☐

Evaluating Significance (for Step 6)

Table 1 Criteria for Evaluating Class of Significance

Magnitude of Effect on VC	Trend of VC	
	Positive	**Negative or Neutral**
Low	Class 1	Class 1
Moderate	Class 1	Class 2
High	Class 2	Class 3

Table 2 Criteria for Evaluating Significance

Project Specific Class on a VC	Overall Class on a VC		
	Low	**Moderate**	**High**
Low			
Moderate		░	▓
High	░	▓	▓

Part 3: Pilot Implementation

Routine screening

In the Absence of Thresholds

A key assumption of the CEAMF is that the screening of projects for cumulative effects should occur now, rather than wait until thresholds are in place. Thus the proposed changes to the OGC screening process can be readily implemented in the absence of thresholds. It is recommended that the routine screening process be tested through a pilot study (similar to that described for thresholds). The pilot study would apply to all areas of northeast BC that are outside areas where candidate thresholds are being tested.

For a recommended six-month period, one selected OGC screening officer would test the proposed changes to the screening process against new project applications. During this period, each application would also be reviewed under the existing process to determine the actual fate of the project (as for the threshold implementation strategy, the fate of the project would not be influenced by the results of the pilot testing).

The OGC screening officer conducting the test would be asked to document any issues or proposed changes to the screening process based on its practical application (see below for the discussion under 'Refinement'). The testing of changes to the screening process would stop should a project be referred to an advanced screen.

In Association with a Threshold Implementation Strategy

Although Volume 2 provides specific candidate numerical thresholds, a process will be required to introduce and formalize their use. Implementation of thresholds will require agreement on definitions of acceptable change, threshold values, a standard public database, a standard process to calculate indicator values using this database, and project-specific and cooperative management actions to be implemented. The existing public database would need to be enhanced and made more readily accessible.

A pilot study is recommended to better understand the ecological, economic, and social implications of threshold implementation in northeast British Columbia. Two areas with existing data and high cumulative effects hazard are proposed for consideration (see Volume 2 for further details). The threshold implementation strategy would coincide with the pilot testing of the proposed amendments to the OGC application screening process (i.e., ACES).

A one-year test period is proposed during which time applications for projects within the selected area(s) would be reviewed by two OGC screening officers: one would apply the existing OGC review process and determine the fate of the application; while the second would apply the proposed amendments to the screening process including the 'threshold test'. During this test period, the results of the 'threshold test' would have no bearing on the fate of an application. However, participation from proponents would be imperative, as proponents would be asked to submit along with their applications a calculation of their project's contribution to the threshold. This would serve to also test the ability of proponents to meet this additional requirement.

The OGC staff conducting the test would be asked to document any issues or proposed changes to the screening process based on its practical application (see below for the discussion under 'Refinement'). The testing of changes to the screening process would stop should a project be referred to an advanced screen. The advanced screening process would be tested separately (see below).

Advanced Screening

Testing of the advanced screener process would not require a parallel application review process such as that proposed for routine projects. Testing of the advanced screener should not occur on a new project application for two reasons. First, the advanced screening is only one part of the expanded review process that would ultimately determine the fate of an application. In the absence of the other two components (referral to OGC Advisory Committee and participation in joint effects management initiatives) the advanced screener alone cannot be fully tested. Second, the advanced screener would require that the proponent undertake a detailed assessment of the effects of the proposed project. As the pilot testing would have no effect on the outcome of the application, it would not be reasonable to require the proponent to invest the additional time and expense of undertaking the advanced screener at this stage.

Rather, the advanced screening process should be tested on an already approved application whereby a selected member of the OGC (or a consultant) would undertake the screening, and a separate OGC screening officer would review the screening report and make a hypothetical decision. Preparation of the advanced screening report would not be conducted by the proponent at this stage but the proponent's involvement would be helpful in two ways: 1) the proponent could help compile necessary information about the project or environment that may not have been included in their original application; and, 2) the proponent would have an opportunity to see how the advanced screener is conducted and provide feedback to the OGC about the implications to industry.

The OGC screening officer conducting the test would be asked to document any issues or proposed changes to the screening process based on its practical application (see below for the discussion under 'Refinement'). It is recommended that a minimum of two approved applications be 're-screened' in this way. A six-month test period is recommended, which would coincide with the test period for the screening of routine applications outside candidate threshold areas.

Refinement

As discussed in Section 4, the concept of a CEAMF relies heavily on the principles of adaptive management. That is, to effectively assess and manage cumulative effects at a regional scale, it is necessary to continually learn from what is being done, update what is known, and adjust practices where necessary. Like the CEAMF as a whole, the application screening process is subject to the same principles. Refinement of ACES would occur at two stages: initially following the pilot implementation period and before formal adoption of the process; and later following one-year of full implementation. The latter stage would involve an independent review of the process, and refinements based on the results of the review.

The review would consider topics such as:

- practical use (e.g., ease of use, clarity of process);
- sufficiency of information available to complete the screening;
- time required to complete different types of screenings;
- appropriateness of thresholds and practical use of thresholds (by proponents and OGC staff);

- reactions of OGC staff , referral agencies and proponents; and
- summary of screening outcomes for routine and advanced applications.

Once pilot implementation, review, and refinement have been completed, the changes to the screening process would be formalized and officially adopted, and any changes from the existing process would need to be clearly communicated to affected parties.

It is also at this stage where the OGC should consider the applicability of the changes to their application review process outside of northeast BC. The proposed screening process has been designed to be readily adaptable to all application types throughout the OGC's areas of jurisdiction[1]; however, as presented here, the northeast BC process makes specific reference to information, data, and components of the proposed CEAMF that would not yet be in place or available elsewhere in the province.

Electronic Information Support System

In recognition of the need for the OGC to rapidly build its internal capability to meet increasing workload and rising expectations for environmental review, the cumulative effects screening process is designed to be implemented in a relatively short-timeframe, with existing resources and making use of the already considerable body of available knowledge and information. However, following an appropriate test and refinement period, OGC staff would benefit from the future design and implementation of an electronic information support system (EISS) that:

- maintains a database of each application processed;
- automatically assigns record numbers when new applications are received and entered to assist with application tracking and archiving information linked to a specific application;
- contains computer-based checklists for routine and advance screenings, including an audit record and decision record;
- references or provides direct links to information sources or spatial databases;
- references or provides direct links to information on assessment tools (e.g., Oil and Gas Project Assessment Matrices);
- provides mapping capability so the proposed project could be mapped in relation to environmental features and other projects in the vicinity (this would require that maps or data themes be readily available and in a compatible format);
- calculates a proposed project's contribution to a threshold;
- identifies and provides information on appropriate effects management measures based on type of project, location, threshold status or other criteria;
- identifies appropriate referrals based on type of project, location, threshold status or other criteria; and
- generates and prints screening reports (and accompanying back-up information) for forwarding to referral agencies or, if a screening is complete, for final approval as necessary by an OGC manager.

---

[1] Some modifications may be necessary to adapt the screener to offshore areas.

Training

OGC staff involved in application review should receive training to best understand how to effectively implement the proposed modifications to their application review process. A half- to one-day training session is proposed, which would cover the following topics:

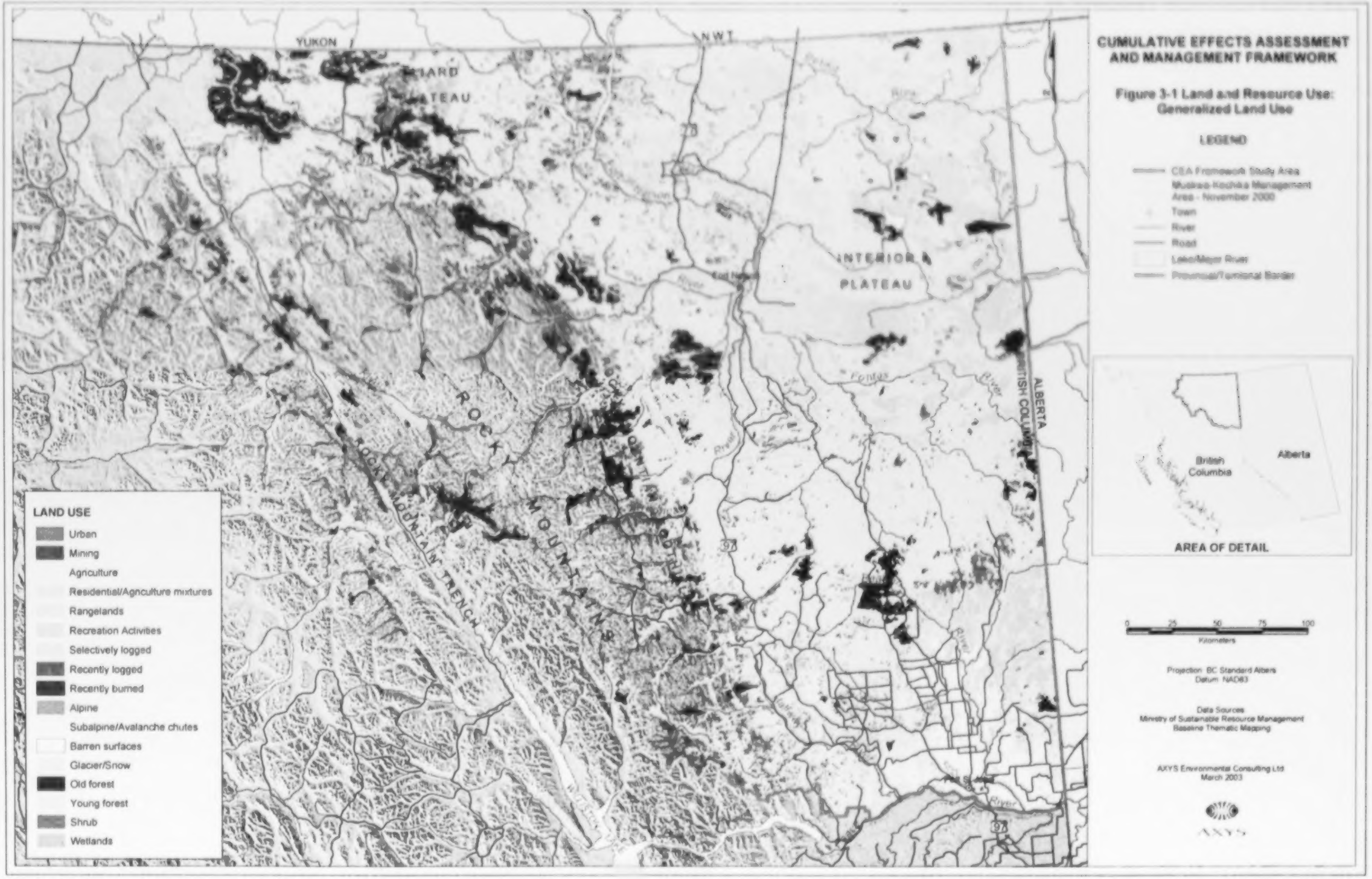
- introduction to concepts and elements of the CEAMF;
- overview of key cumulative effects issues in northeast BC with specific reference to oil and gas related activities;
- overview of proposed changes to the OGC application screening process;
- overview of requirements of OGC staff (e.g., information, time);
- detailed description of the steps in the routine screening process: conformance, thresholds, effects assessment, effects management, monitoring; and decision;
- overview of the advanced screening process and the role of OGC staff in guiding the proponent through the process;
- discussion and questions; and
- implementation (i.e., 'how to get started').

Appendix H: Oversize Maps

Table H-1. List of Baseline and Hot Spot Maps

Figure Title		Fig. #
Component	**Description**[1]	
Land and Resource Use	Generalized Land Use	3-1
	Residential Settlement and Transportation	3-2
	Pipelines and Wellpads	3-3
	Seismic Line Density	3-4
	Protected Areas	3-5
	LRMPs Overlapping Study Area	3-6
	Fort Nelson LRMP	3-7
	Fort St. John LRMP	3-8
	MacKenzie LRMP	3-9
Air Quality	Well Density	3-10
	Hot spots (Sulphur Emissions)	3-11
Soils and Terrain	Soils Classification	3-12
	Soil Hot spots (Acid Sensitivity)	3-13
	Soil Hot spots (Erosion Risk)	3-14
Aquatic Ecosystems	Arctic Grayling and Bull Trout Observations	3-15
	Hot spots (Drainages)	3-16
Vegetation	Biogeoclimatic Zones	3-17
	Sensitive Features	3-18
	Hot spots (Sensitive Features)	3-19
Wildlife	Grizzly Bear Habitat Capability	3-20
	Moose Habitat Capability	3-21
	Marten Habitat Capability	3-22
	Warbler Habitat Capability	3-23
	Caribou Winter Habitat	3-24
	Grizzly Bear Hot spots (Habitat Capability)	3-25
	Moose Hot spots (Habitat Capability)	3-26
	Marten Hot spots (Habitat Capability)	3-27
	Warbler Hot spots (Habitat Capability)	3-28
	Caribou Hot spots (Winter Habitat)	3-29
Disturbance	Disturbance Coverage	E-1

[1] Shaded cells indicate hot spot maps; remaining cells are baseline maps.



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-1 Land and Resource Use: Generalized Land Use

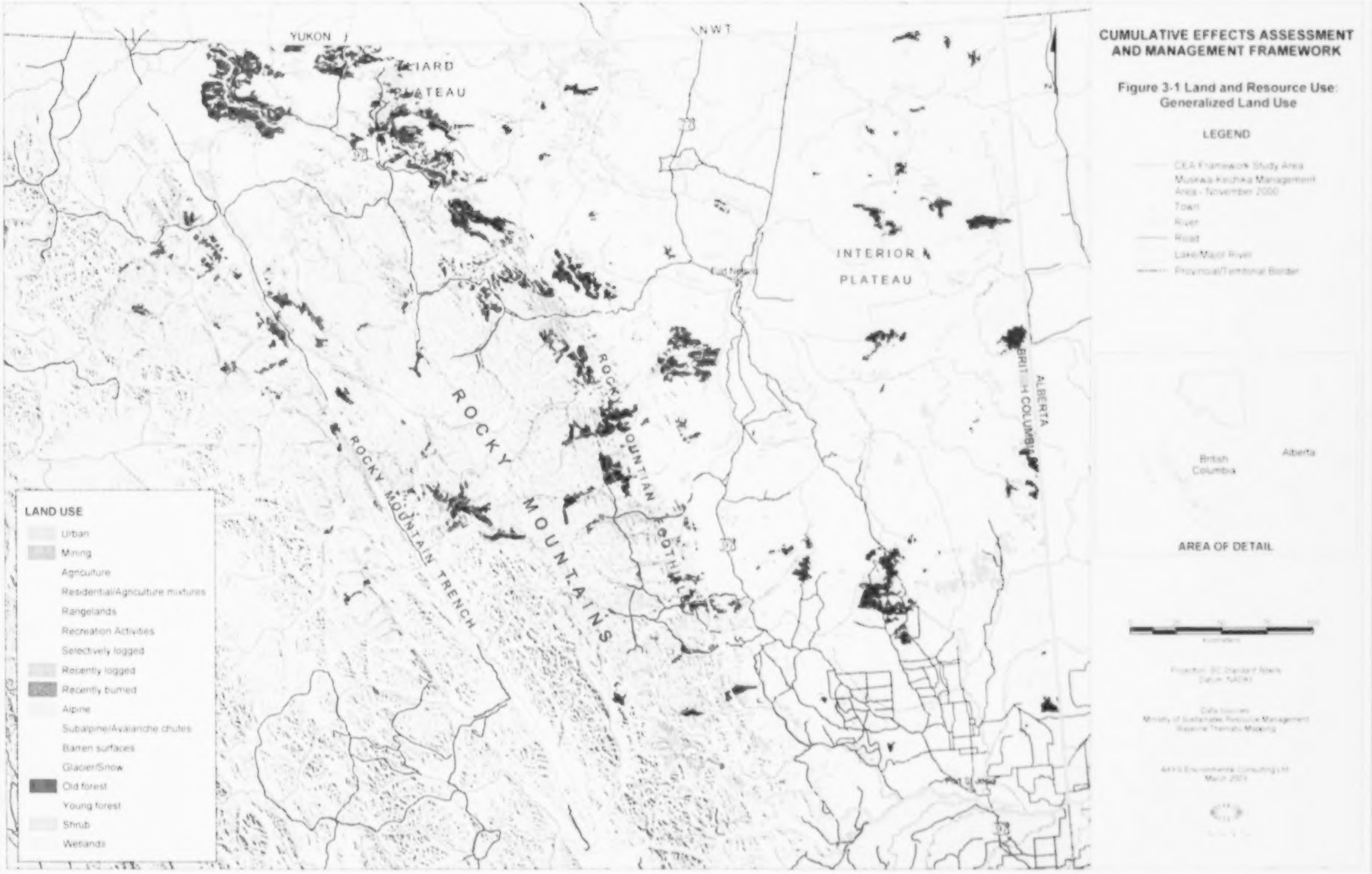
Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Baseline Thematic Mapping

AXYS Environmental Consulting Ltd
March 2003

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

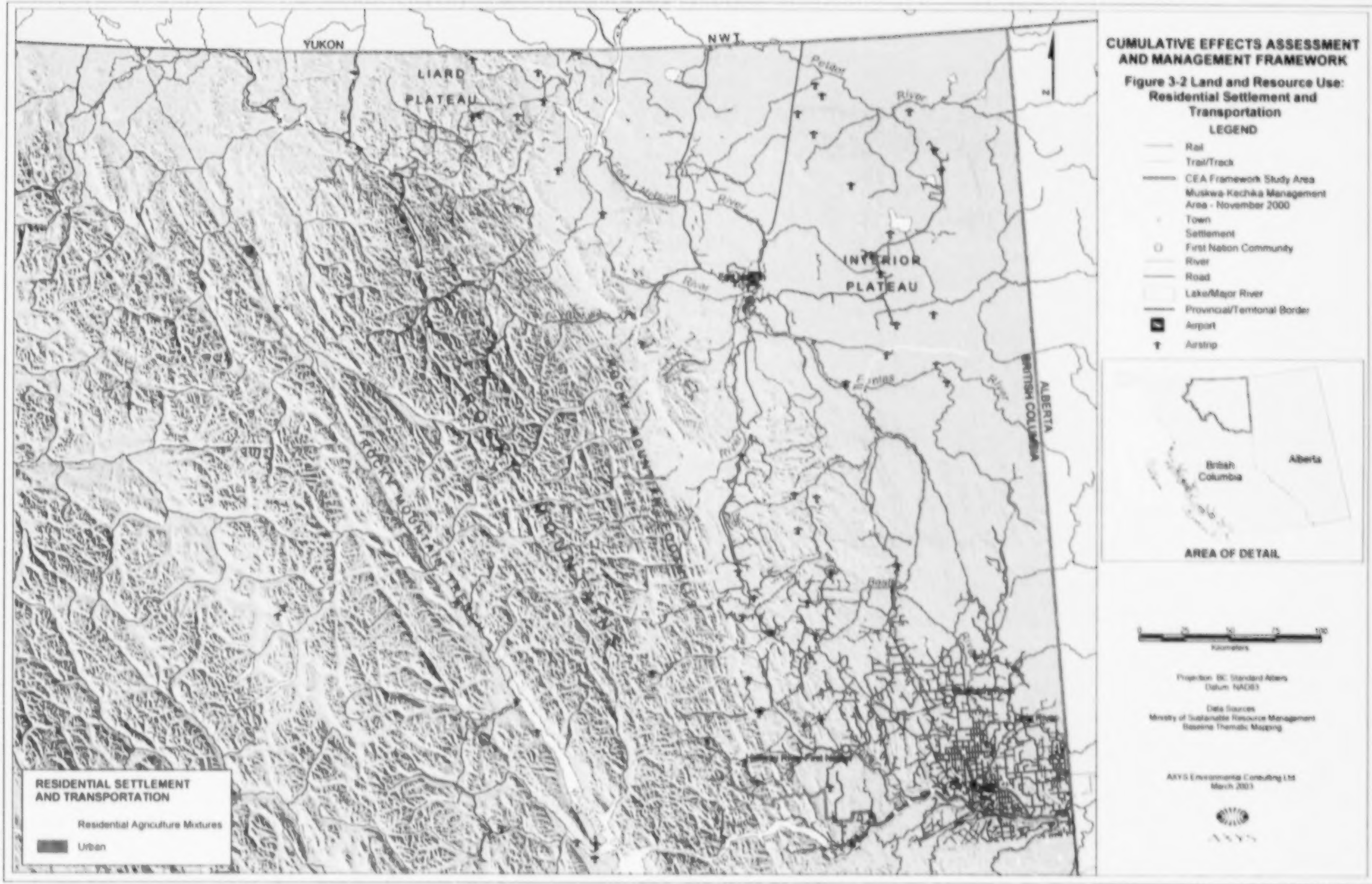
Figure 3-1 Land and Resource Use: Generalized Land Use



Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management
Baseline Thematic Mapping

AXYS Environmental Consulting Ltd.
March 2001



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

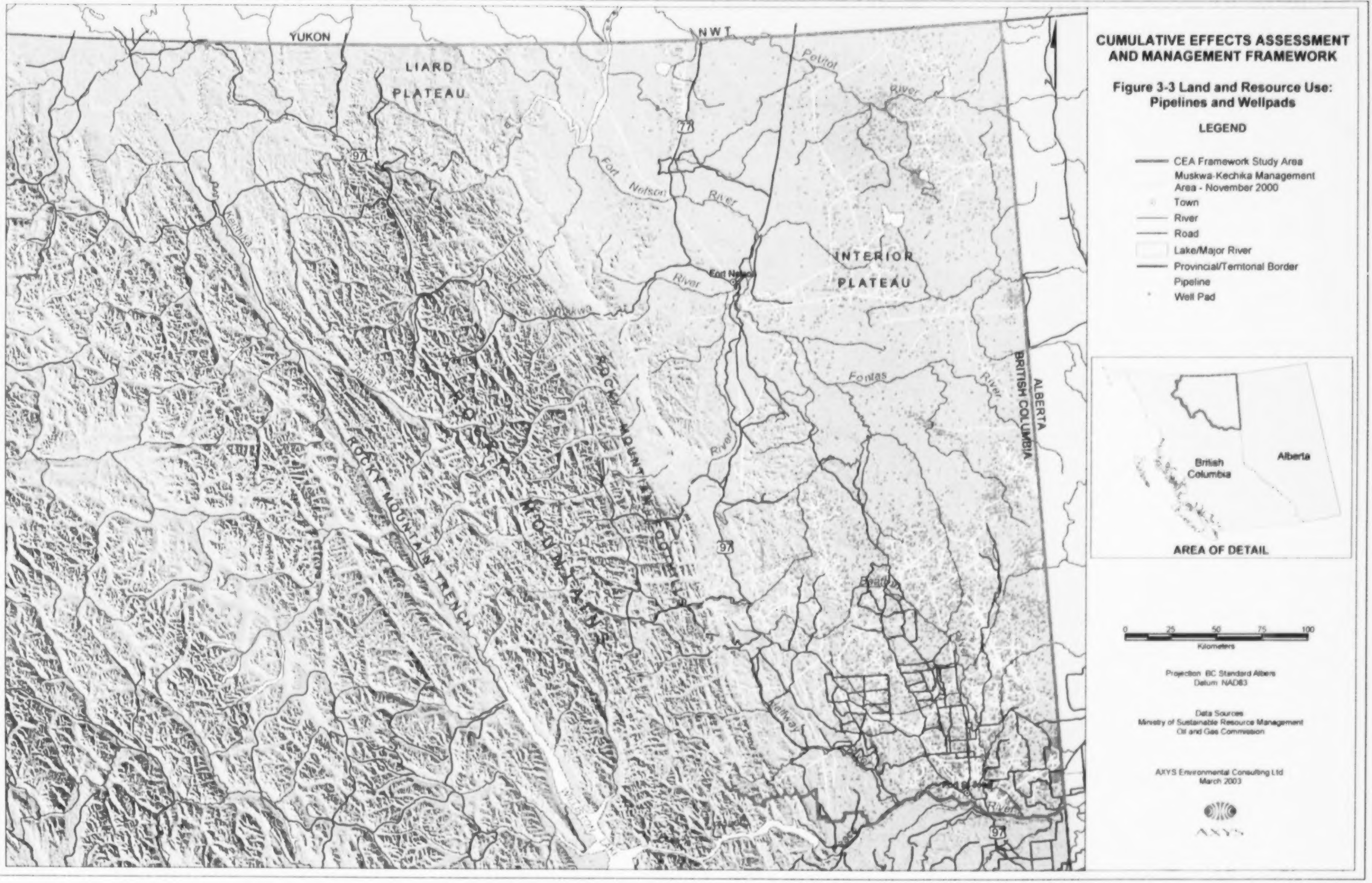
Figure 3-2 Land and Resource Use: Residential Settlement and Transportation

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Baseline Thematic Mapping

AXYS Environmental Consulting Ltd
March 2003

AXYS



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-3 Land and Resource Use: Pipelines and Wellpads

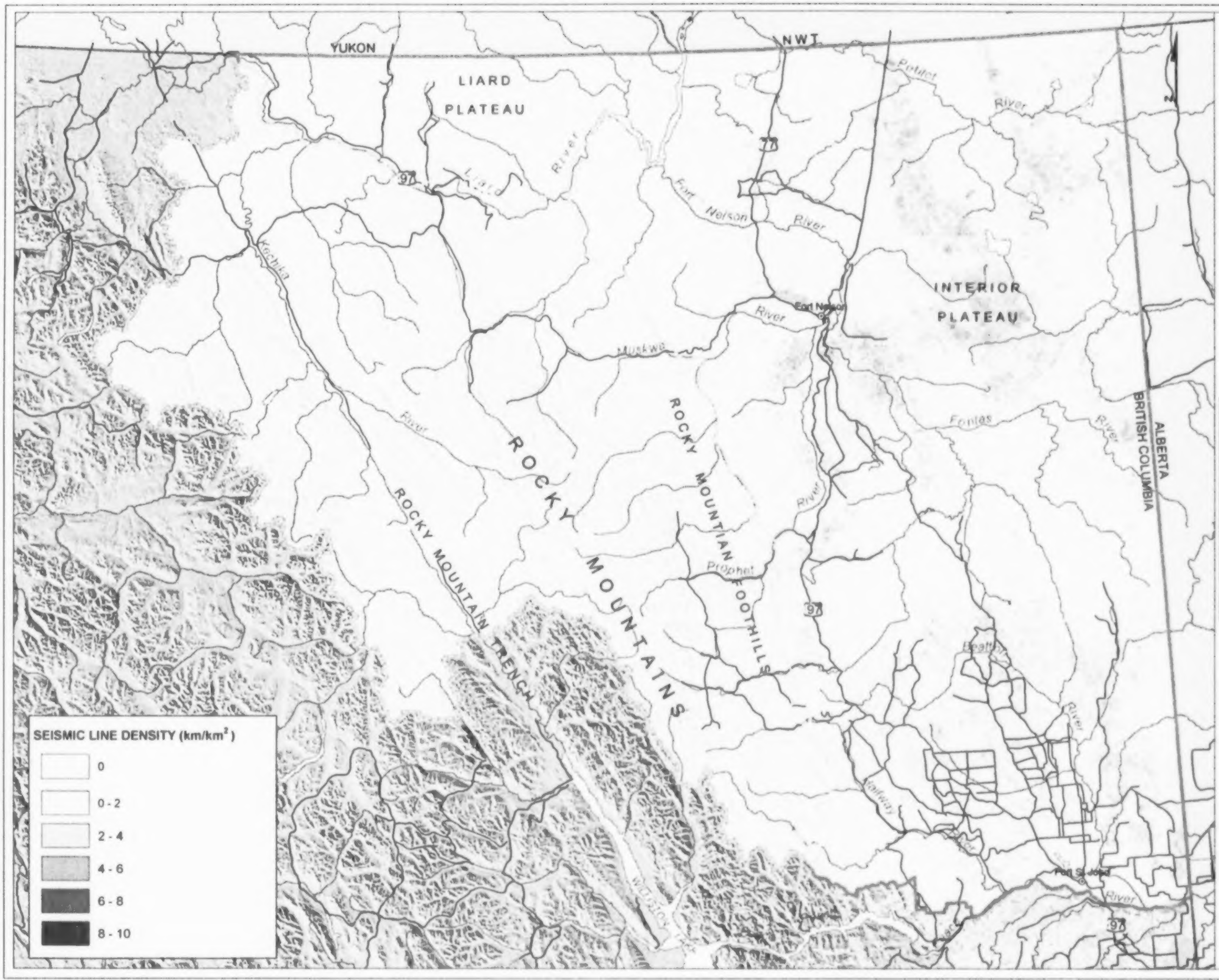
Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Oil and Gas Commission

AXYS Environmental Consulting Ltd
March 2003

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-4 Land and Resource Use: Seismic Line Density



Projection: BC Standard Albers
Datum: NAD83

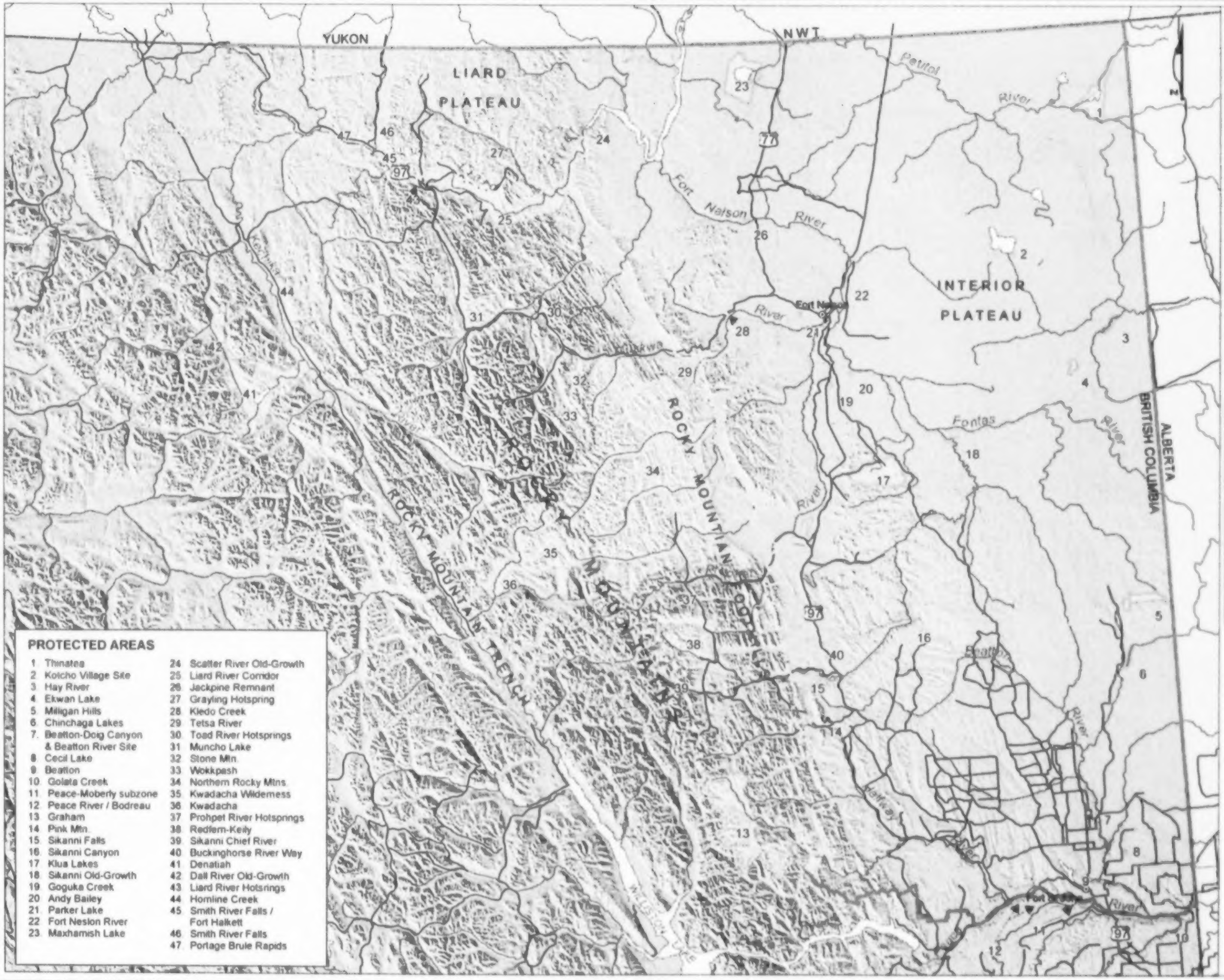
Data Sources
Ministry of Sustainable Resource Management
Oil and Gas Commission

AXYS Environmental Consulting Ltd
March 2003

AXYS

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-5 Land and Resource Use: Protected Areas



PROTECTED AREAS

1 Thinatea
2 Kotcho Village Site
3 Hay River
4 Ekwan Lake
5 Milligan Hills
6 Chinchaga Lakes
7. Beatton-Doig Canyon & Beatton River Site
8 Cecil Lake
9 Beatton
10 Golata Creek
11 Peace-Moberly subzone
12 Peace River / Bodreau
13 Graham
14 Pink Mtn.
15 Sikanni Falls
16 Sikanni Canyon
17 Klua Lakes
18 Sikanni Old-Growth
19 Goguka Creek
20 Andy Bailey
21 Parker Lake
22 Fort Neslon River
23 Maxhamish Lake
24 Scatter River Old-Growth
25 Liard River Corridor
26 Jackpine Remnant
27 Grayling Hotspring
28 Kledo Creek
29 Tetsa River
30 Toad River Hotsprings
31 Muncho Lake
32 Stone Mtn.
33 Wokkpash
34 Northern Rocky Mtns.
35 Kwadacha Wilderness
36 Kwadacha
37 Prohpet River Hotsprings
38 Redfern-Keily
39 Sikanni Chief River
40 Buckinghorse River Way
41 Denatiah
42 Dall River Old-Growth
43 Liard River Hotsrings
44 Hornline Creek
45 Smith River Falls / Fort Halkett
46 Smith River Falls
47 Portage Brule Rapids

LEGEND

- CEA Framework Study Area
- Muskwa-Kechika Management Area - November 2000
- Town
- River
- Road
- Lake/Major River
- Provincial/Territorial Border
- Protected Area

AREA OF DETAIL

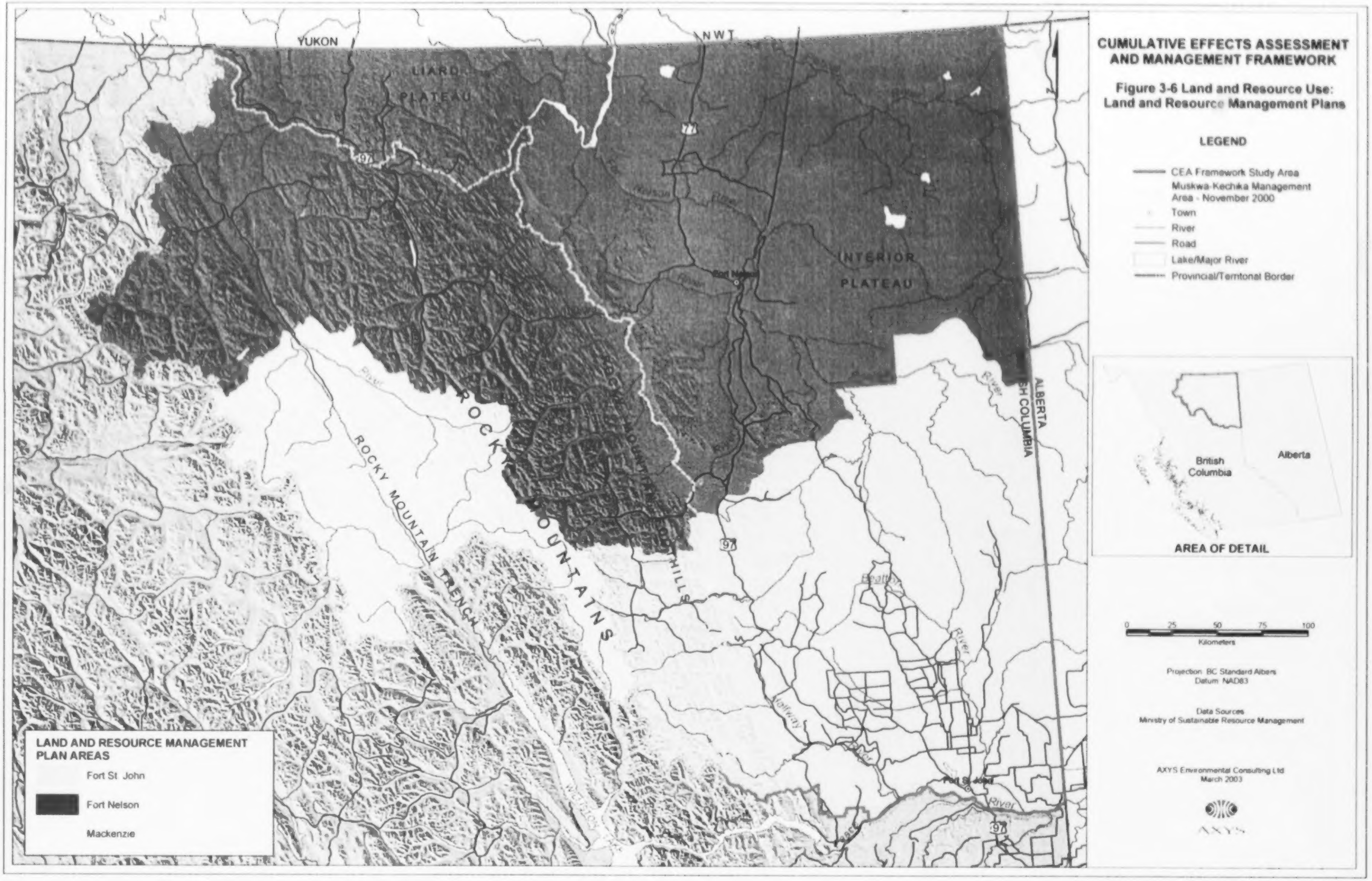
0 25 50 75 100
Kilometers

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management

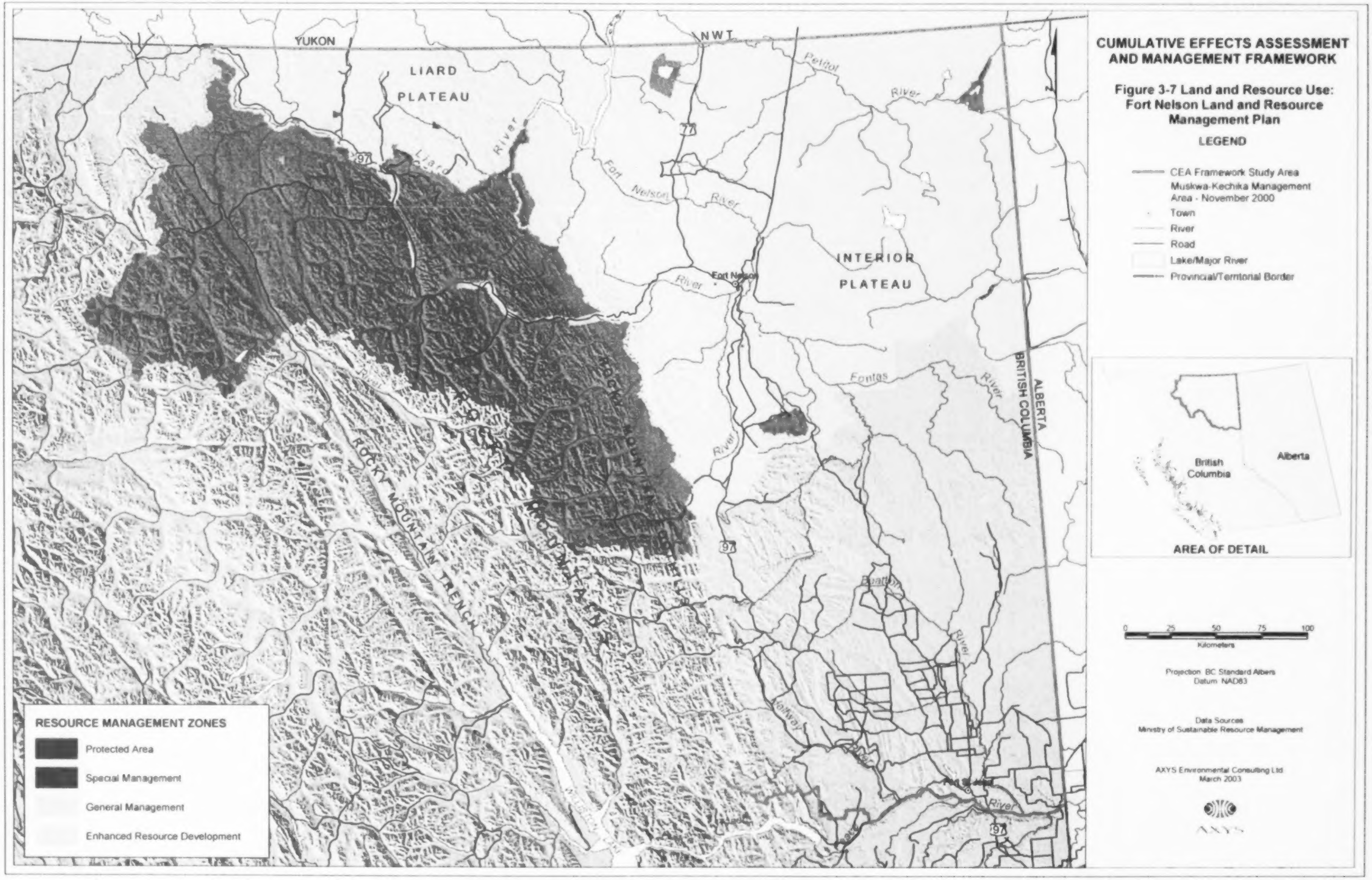
AXYS Environmental Consulting Ltd
March 2003

AXYS



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-6 Land and Resource Use: Land and Resource Management Plans



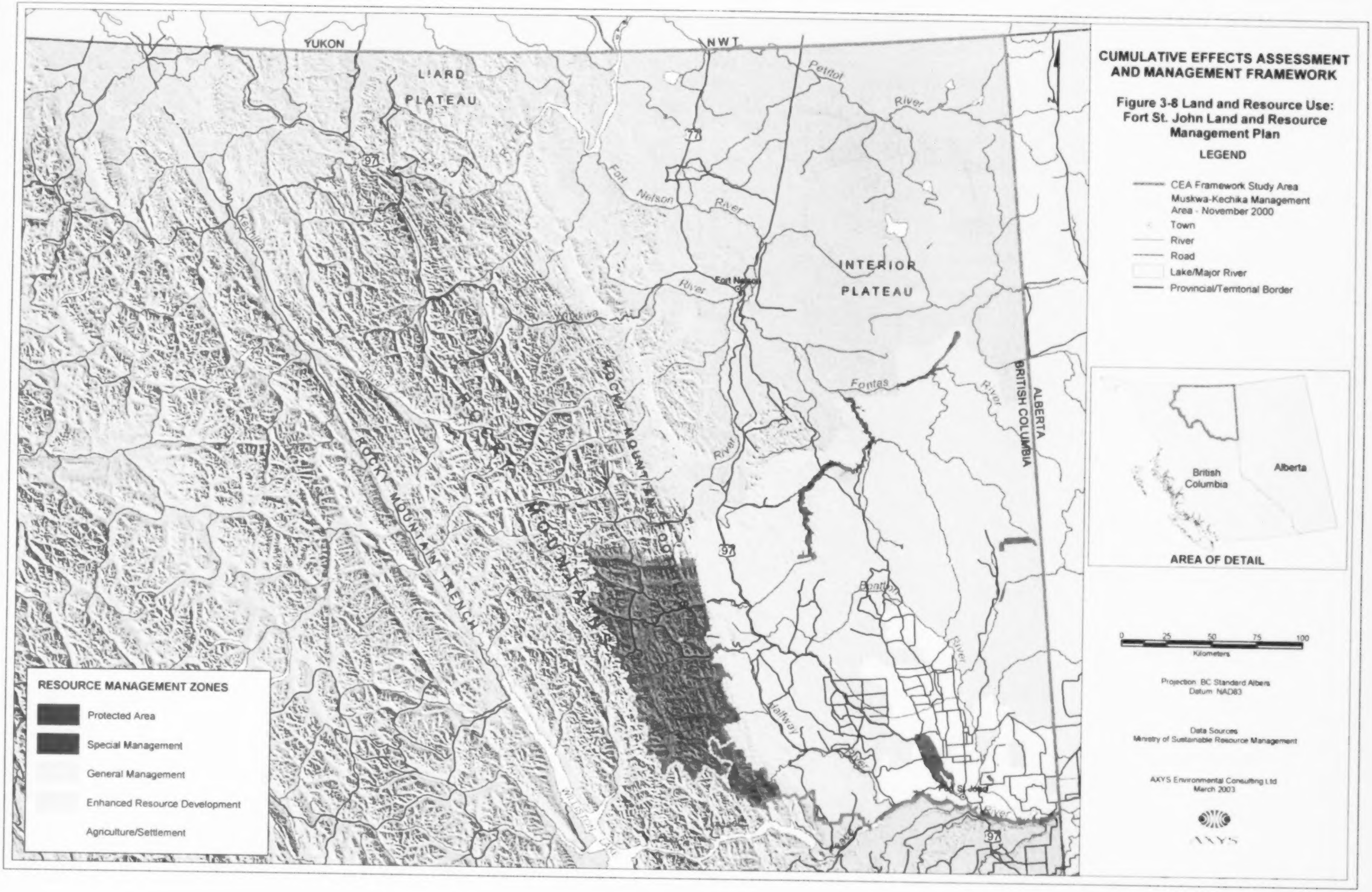
CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-7 Land and Resource Use: Fort Nelson Land and Resource Management Plan

Projection BC Standard Albers
Datum NAD83

Data Sources
Ministry of Sustainable Resource Management

AXYS Environmental Consulting Ltd
March 2003



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-8 Land and Resource Use: Fort St. John Land and Resource Management Plan

LEGEND

- CEA Framework Study Area
- Muskwa-Kechika Management Area - November 2000
- Town
- River
- Road
- Lake/Major River
- Provincial/Territorial Border

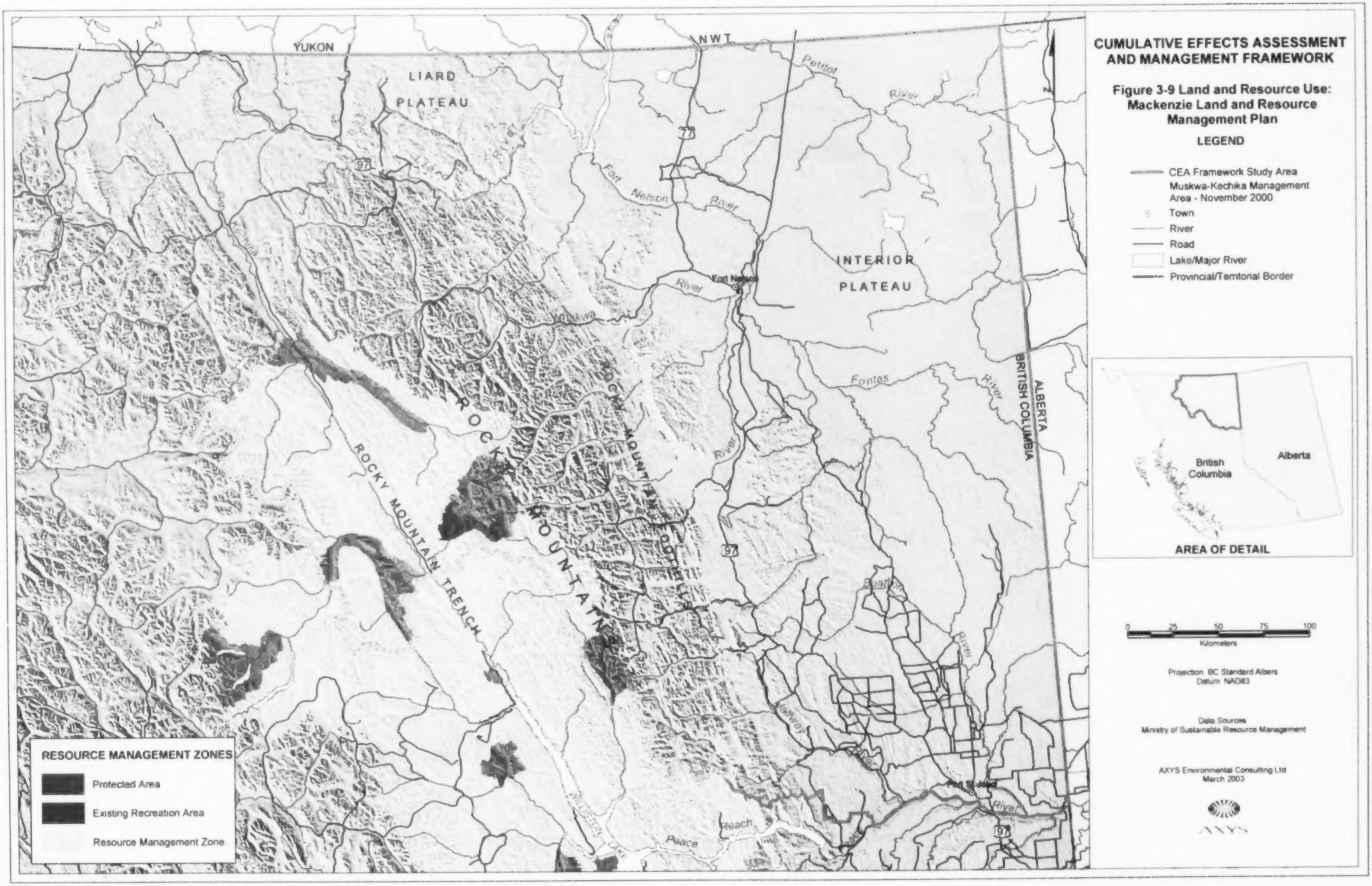
RESOURCE MANAGEMENT ZONES

- Protected Area
- Special Management
- General Management
- Enhanced Resource Development
- Agriculture/Settlement

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management

AXYS Environmental Consulting Ltd
March 2003



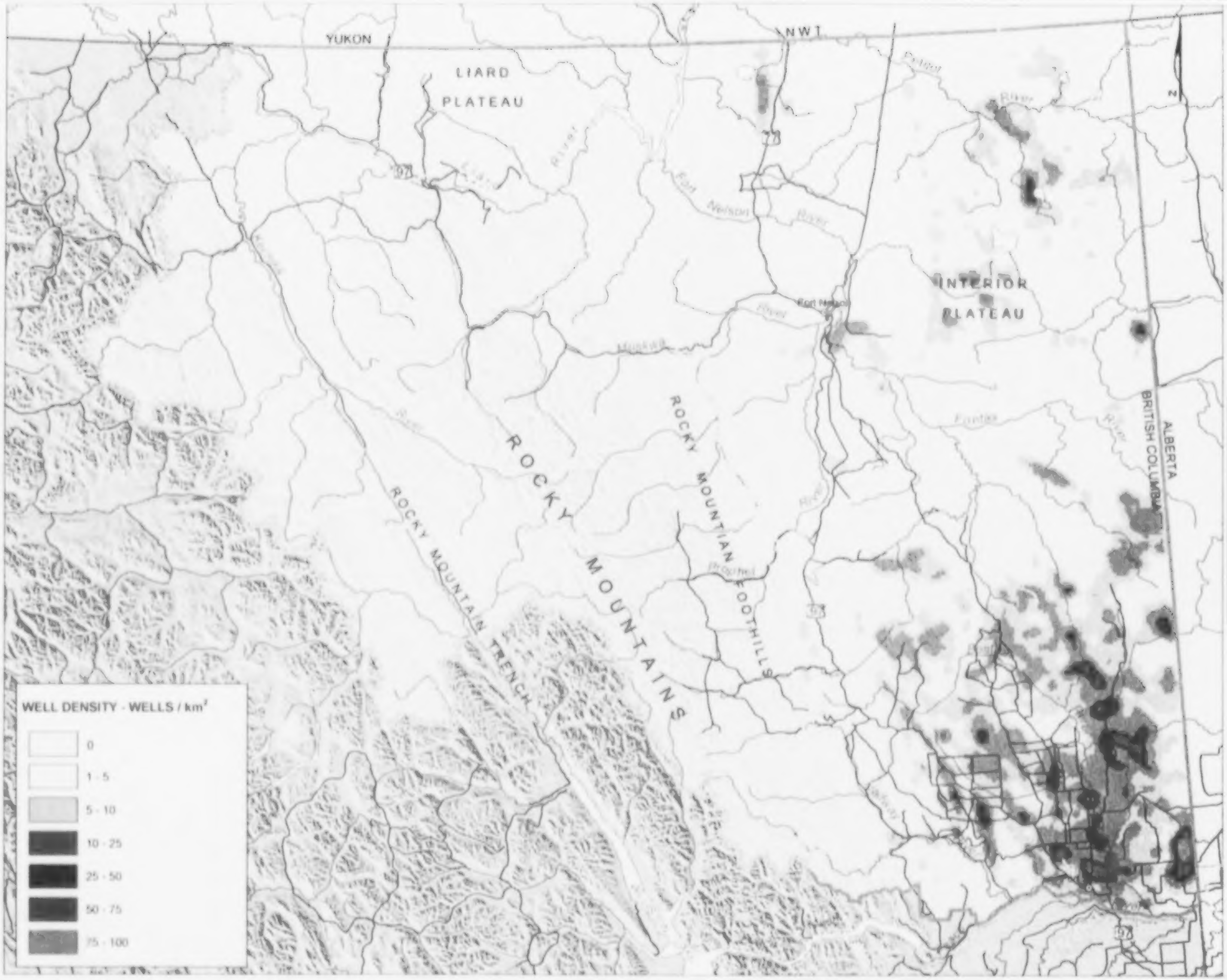
CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-9 Land and Resource Use: Mackenzie Land and Resource Management Plan

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management

AXYS Environmental Consulting Ltd.
March 2003



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-10 Air Quality: Well Density

LEGEND

CEA Framework Study Area
Muskwa-Kechika Management Area - November 2000
Town
River
Road
Lake/Major River
Provincial/Territorial Border

AREA OF DETAIL

0 25 50 75 100
Kilometers

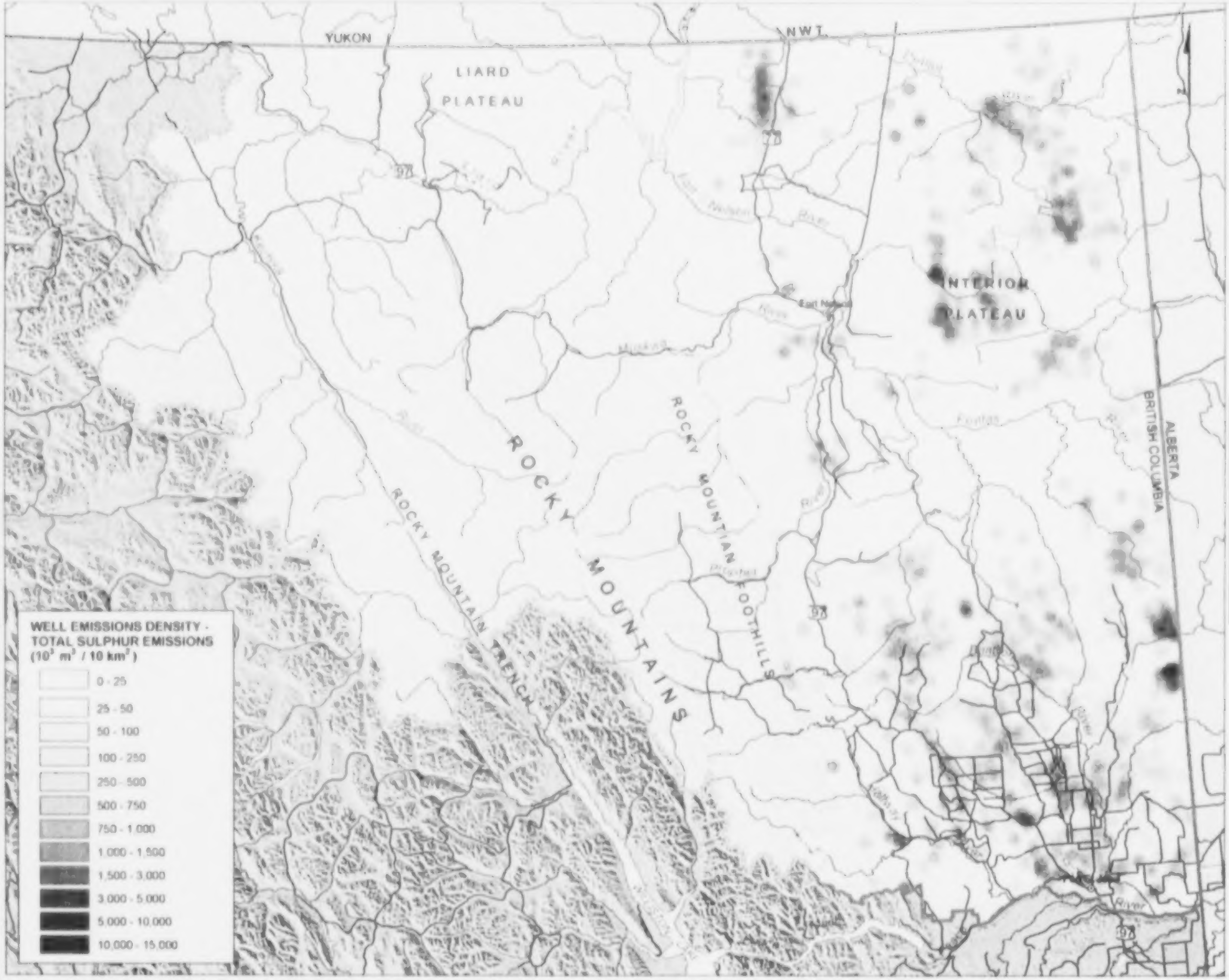
Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Oil and Gas Commission

AXYS Environmental Consulting Ltd
March 2003

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-11 Air Quality:
Hot Spots (Sulphur Emissions)



LEGEND

CEA Framework Study Area
Muskwa-Kechika Management Area - November 2000
Town
River
Road
Lake/Major River
Provincial/Territorial Border

AREA OF DETAIL

Projection: BC Standard Albers
Datum: NAD83

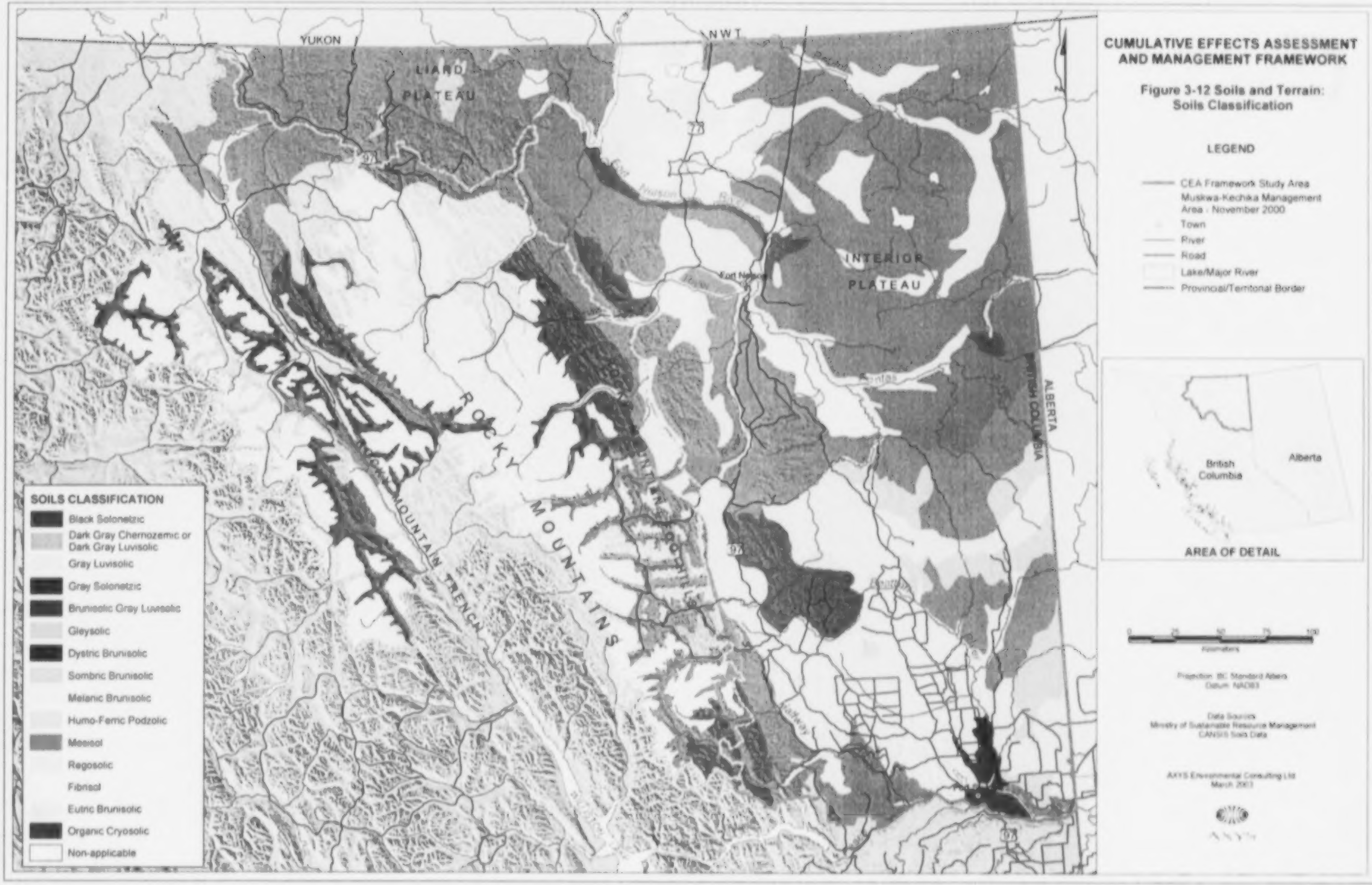
Data Sources
Ministry of Sustainable Resource Management
Oil and Gas Commission

AXYS Environmental Consulting Ltd
March 2003

AXYS

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

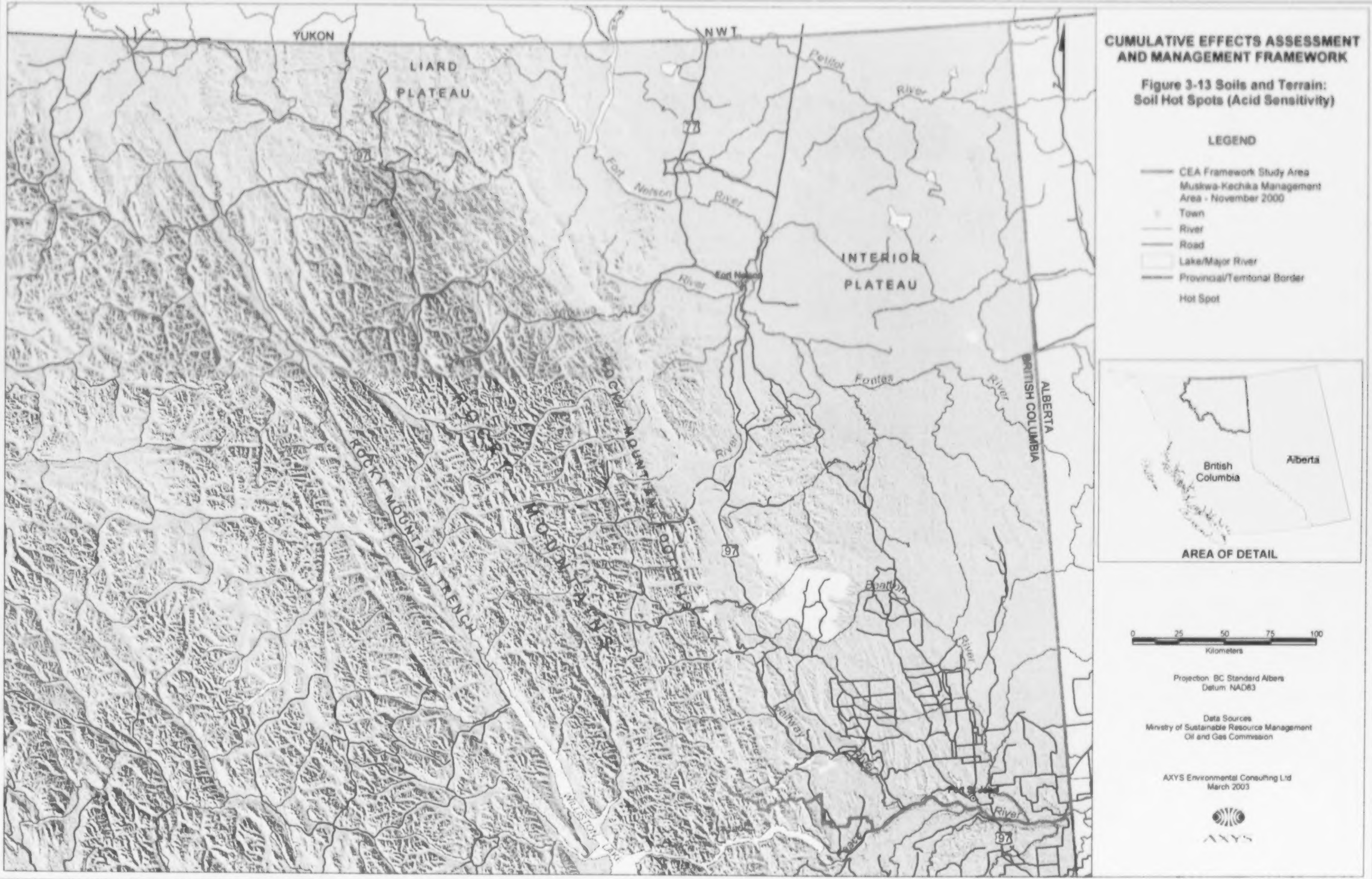
Figure 3-12 Soils and Terrain: Soils Classification



Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
CANSIS Soils Data

AXYS Environmental Consulting Ltd
March 2003



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-13 Soils and Terrain: Soil Hot Spots (Acid Sensitivity)

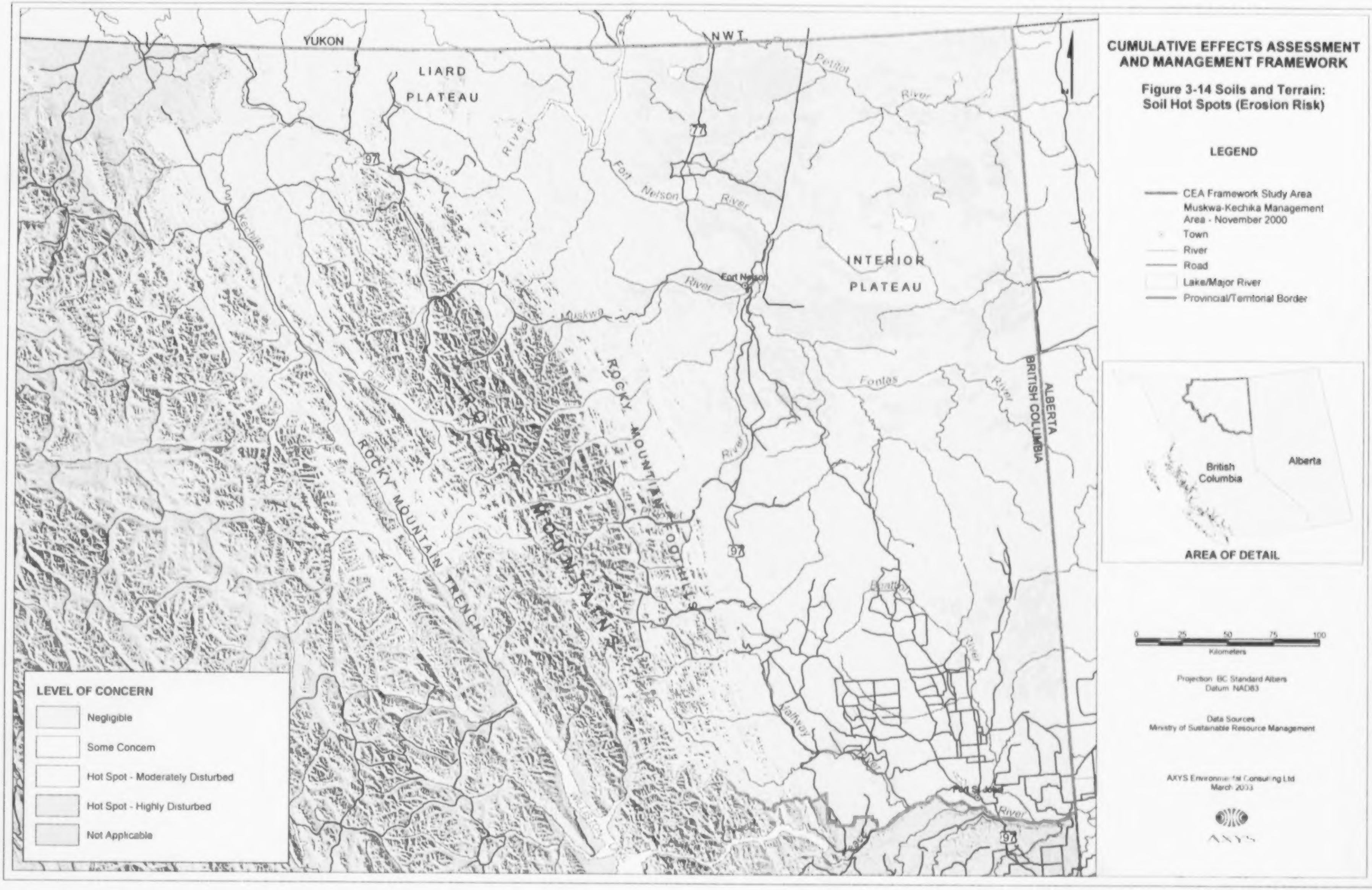
Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Oil and Gas Commission

AXYS Environmental Consulting Ltd
March 2003

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

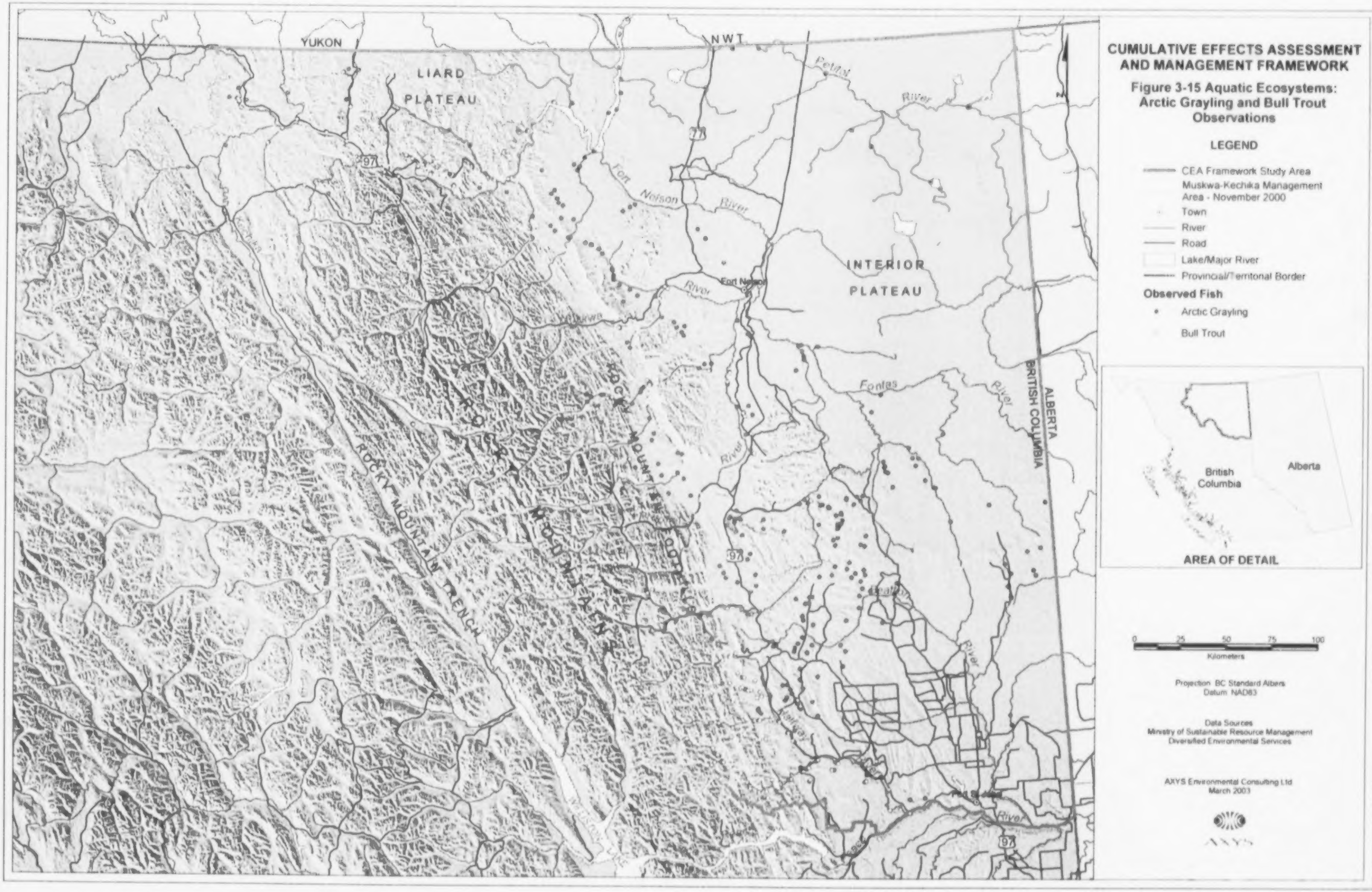
Figure 3-14 Soils and Terrain: Soil Hot Spots (Erosion Risk)



Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management

AXYS Environmental Consulting Ltd
March 2003



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-15 Aquatic Ecosystems: Arctic Grayling and Bull Trout Observations

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Diversified Environmental Services

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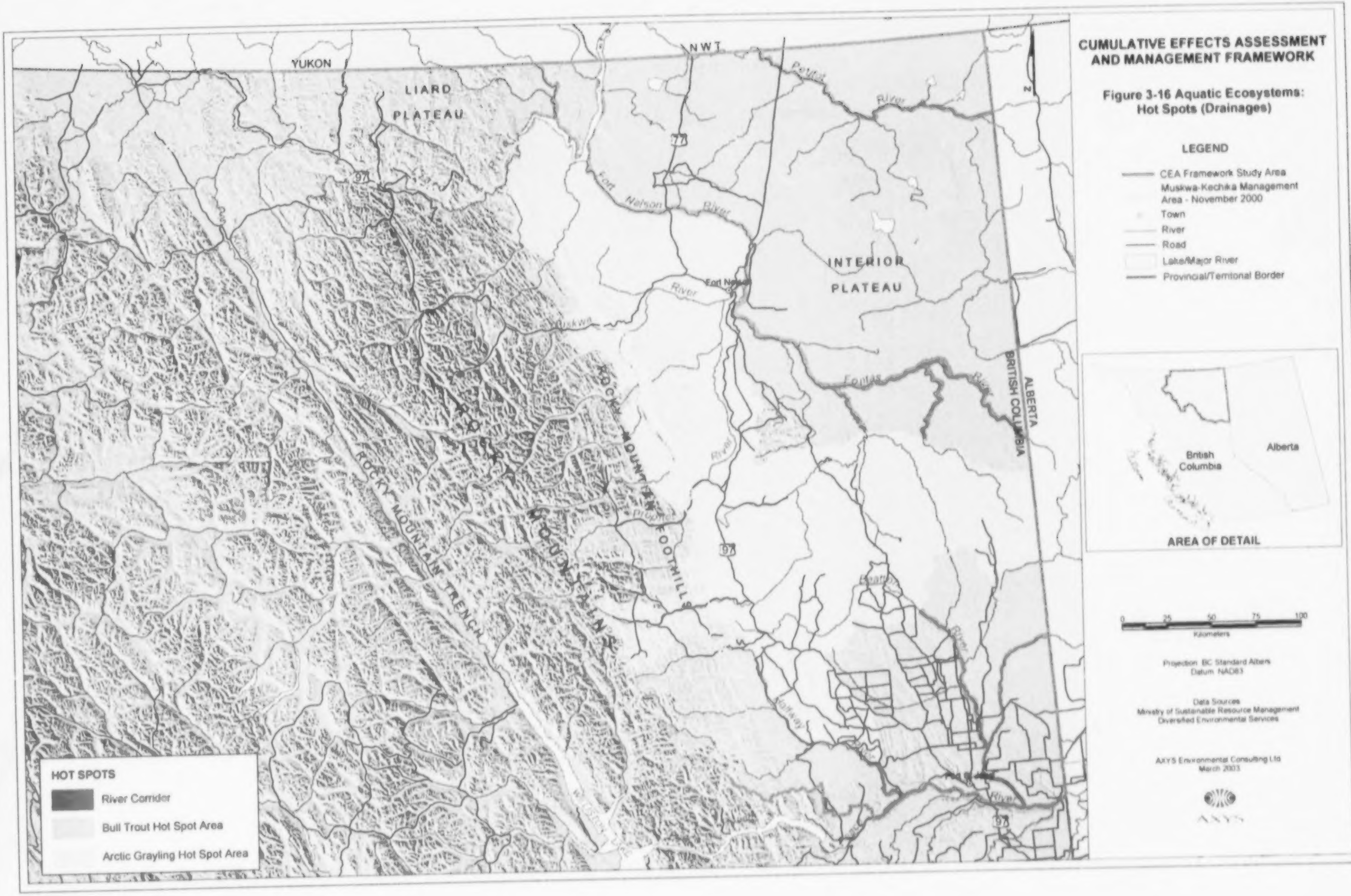

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-16 Aquatic Ecosystems: Hot Spots (Drainages)

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Diversified Environmental Services

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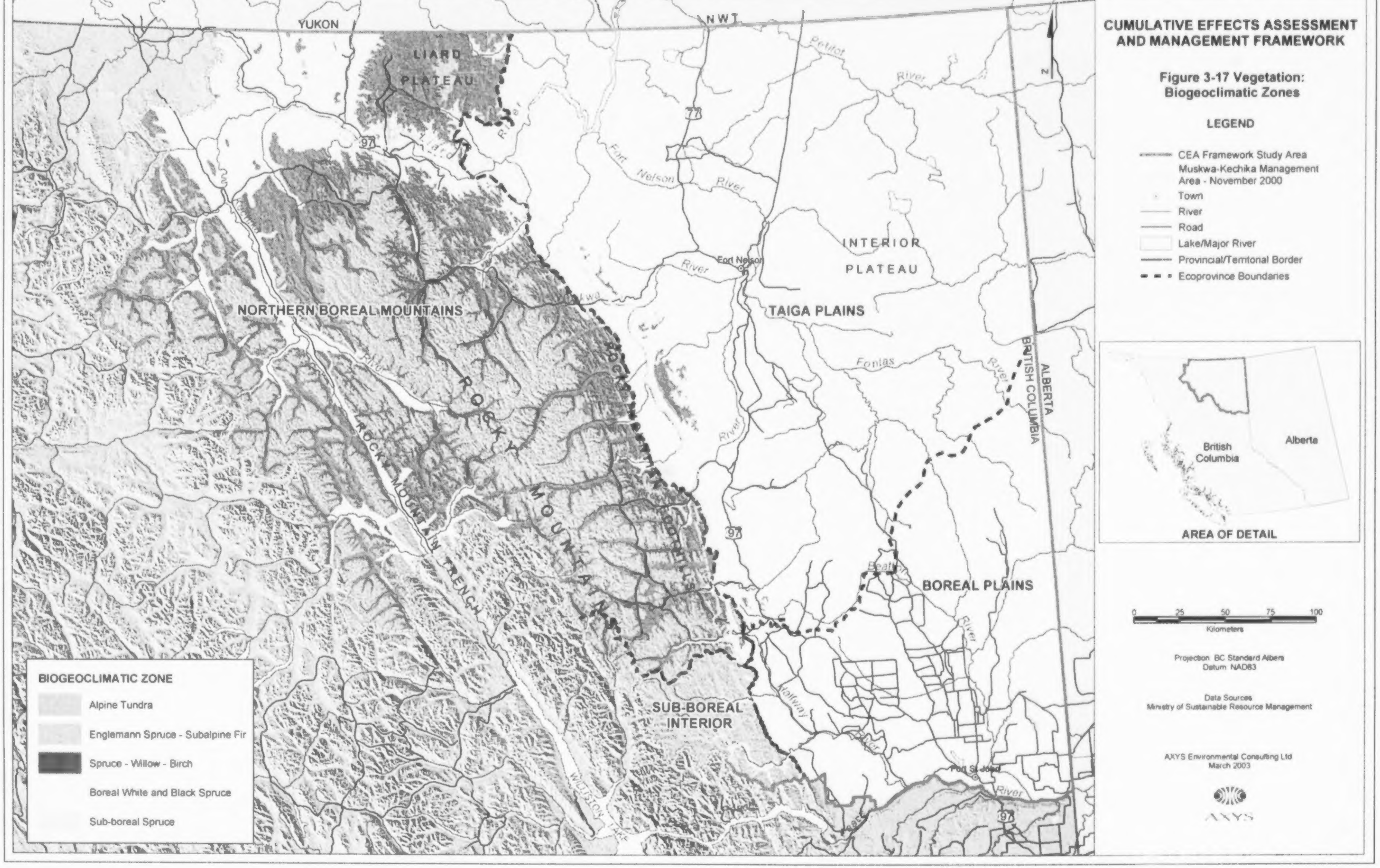

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-17 Vegetation: Biogeoclimatic Zones

LEGEND

- CEA Framework Study Area
- Muskwa-Kechika Management Area - November 2000
- Town
- River
- Road
- Lake/Major River
- Provincial/Territorial Border
- Ecoprovince Boundaries

Projection BC Standard Albers
Datum NAD83

Data Sources
Ministry of Sustainable Resource Management

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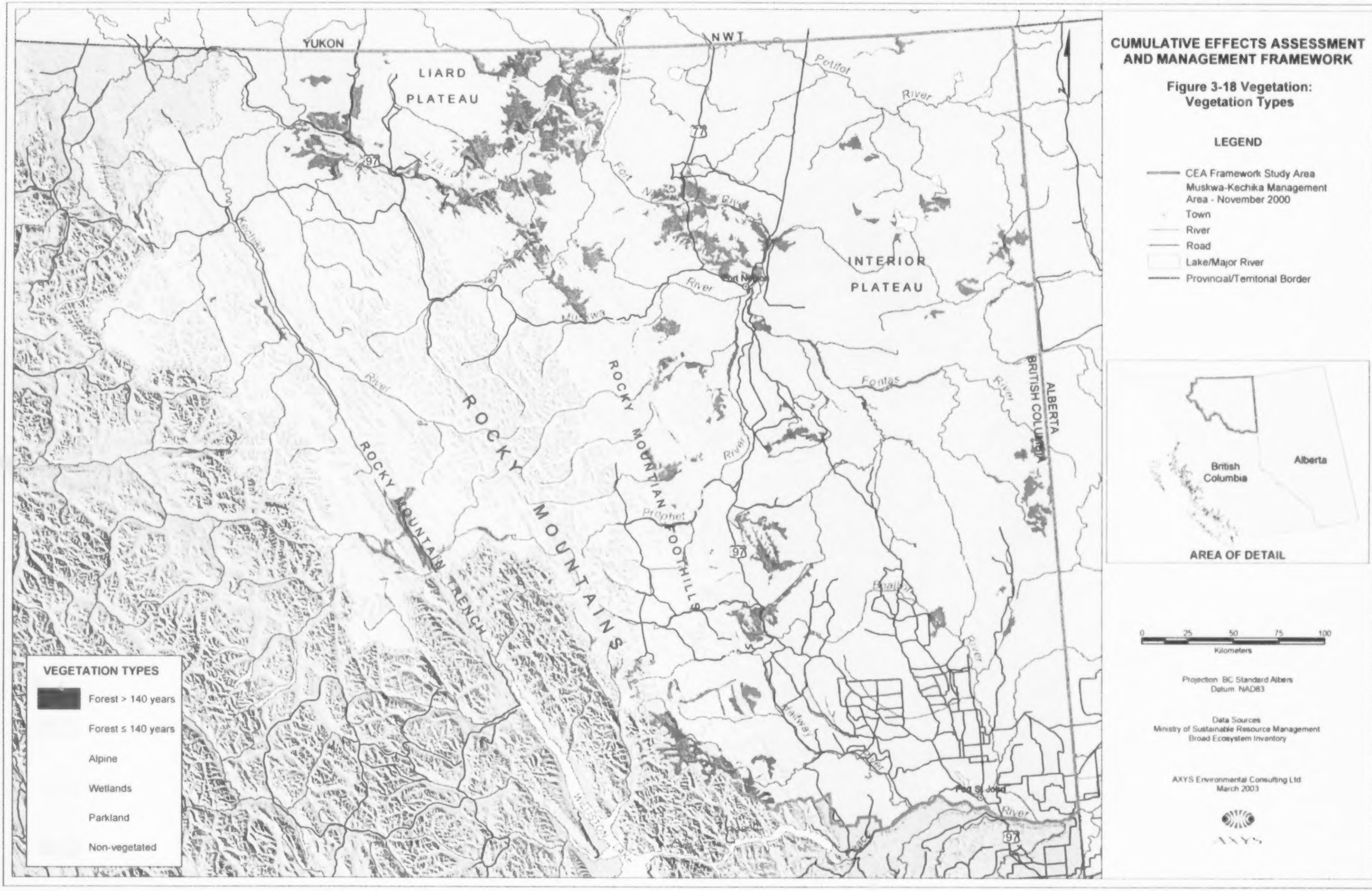

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-18 Vegetation: Vegetation Types

Projection BC Standard Albers
Datum NAD83

Data Sources
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory

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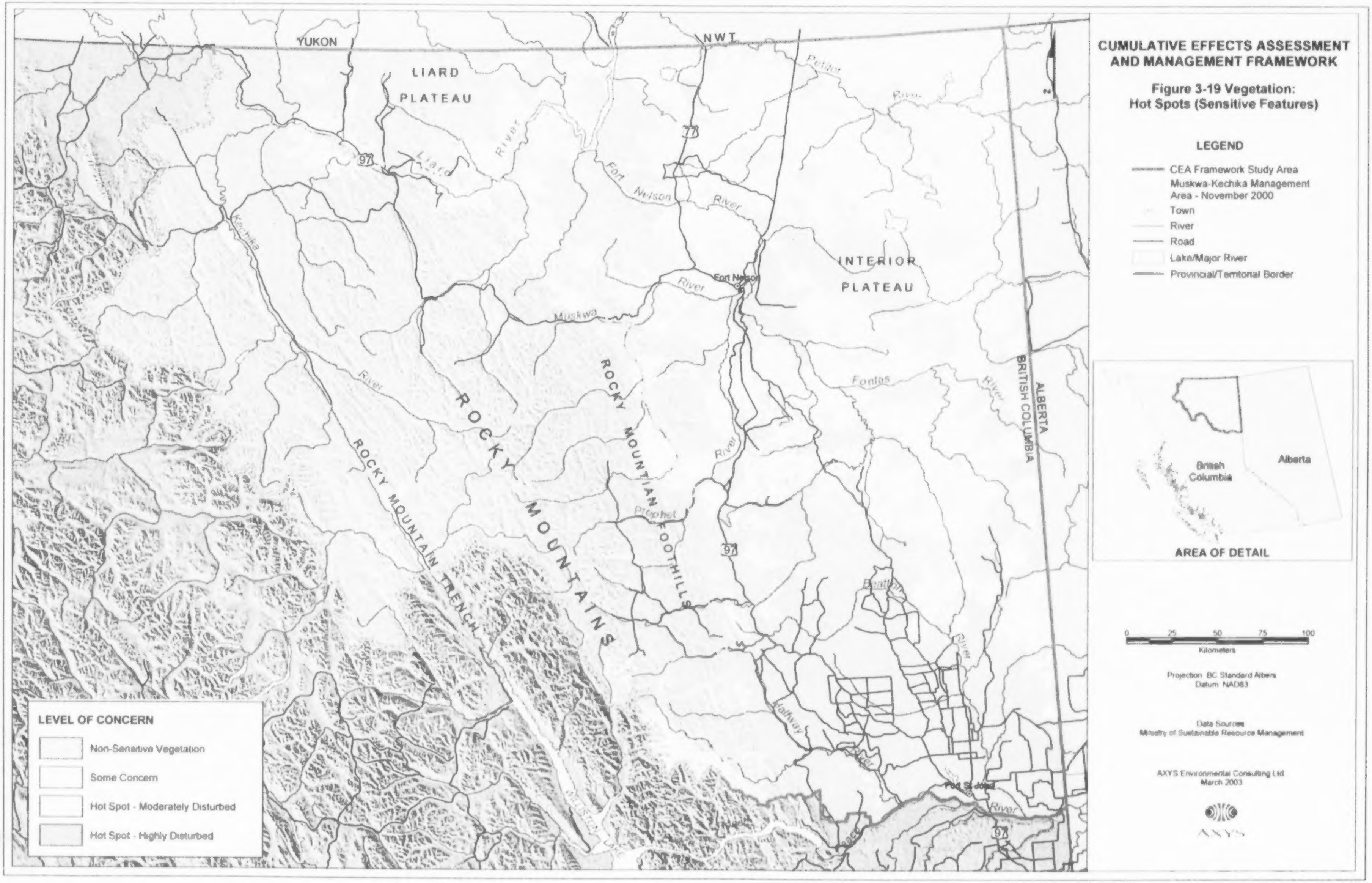

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-19 Vegetation: Hot Spots (Sensitive Features)

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management

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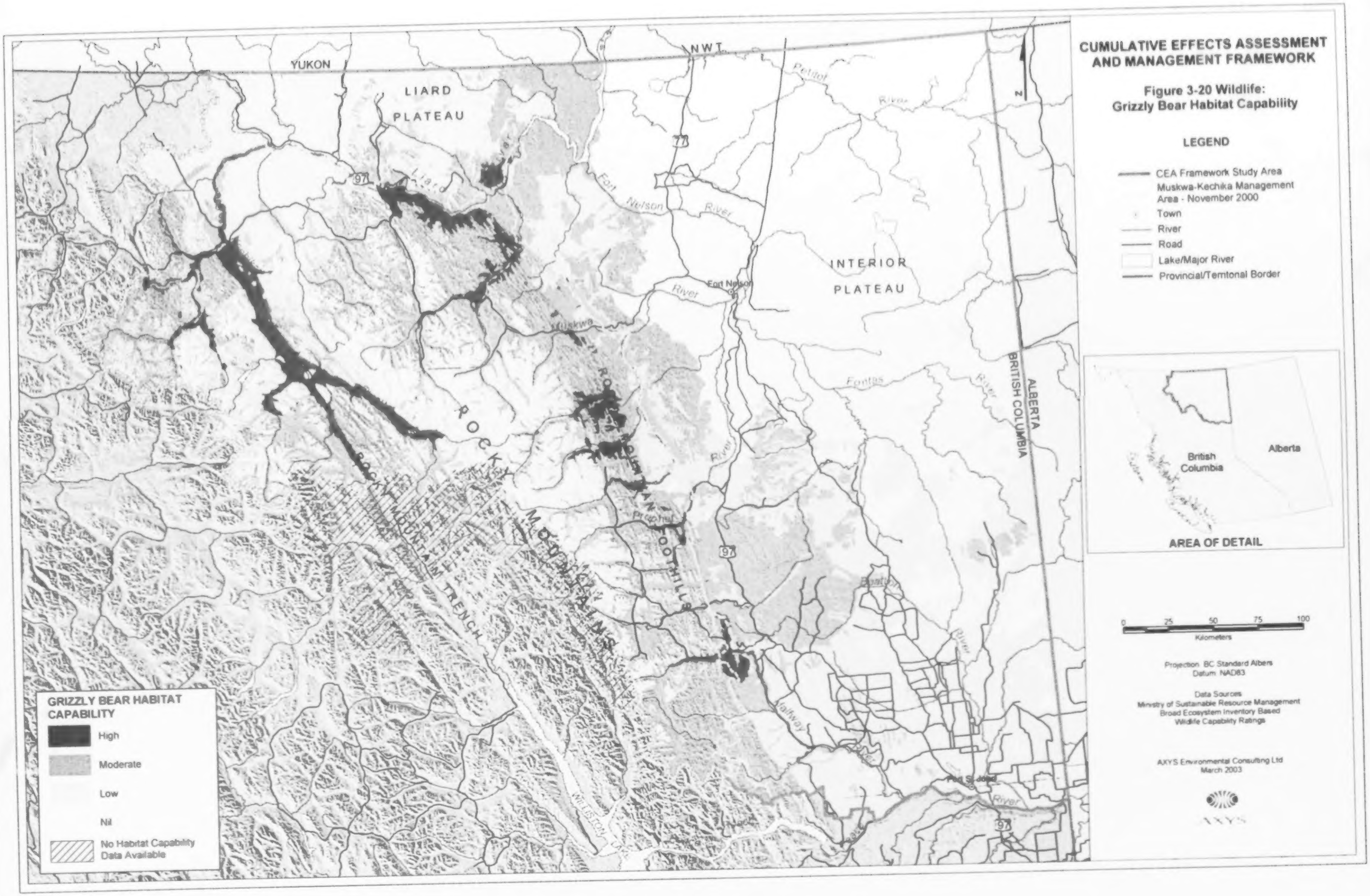

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-20 Wildlife: Grizzly Bear Habitat Capability

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based
Wildlife Capability Ratings

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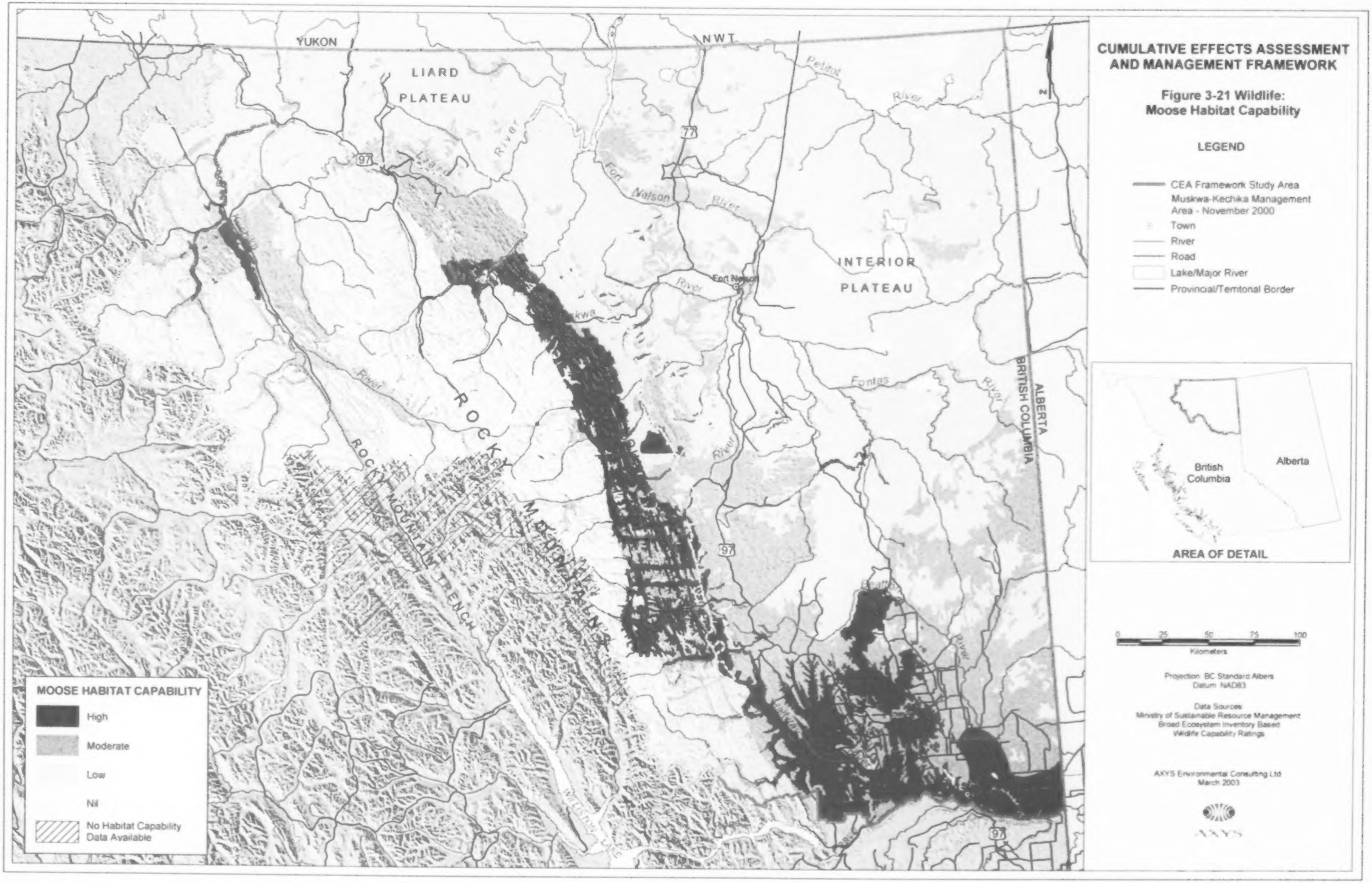

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-21 Wildlife: Moose Habitat Capability

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based
Wildlife Capability Ratings

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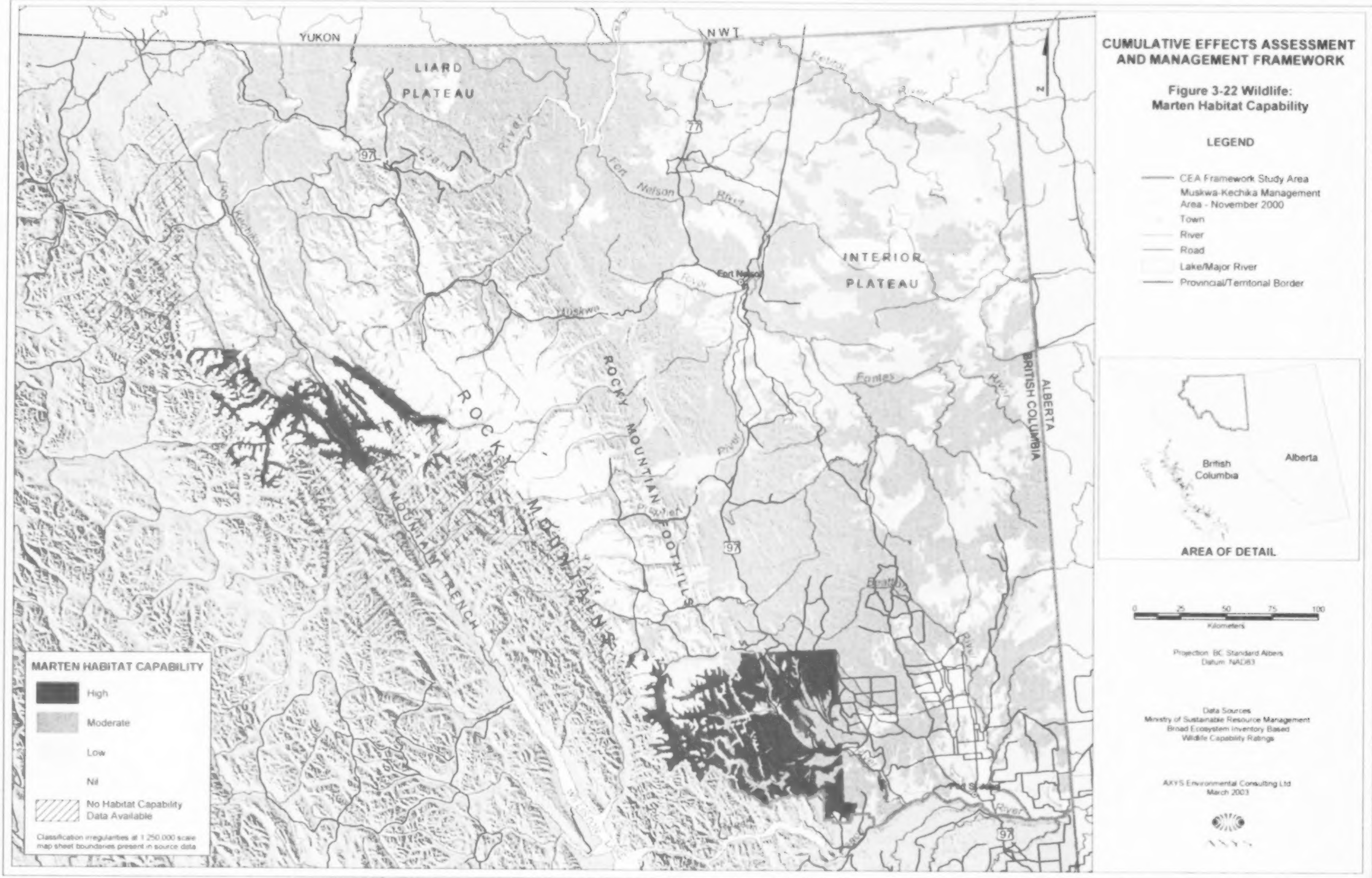
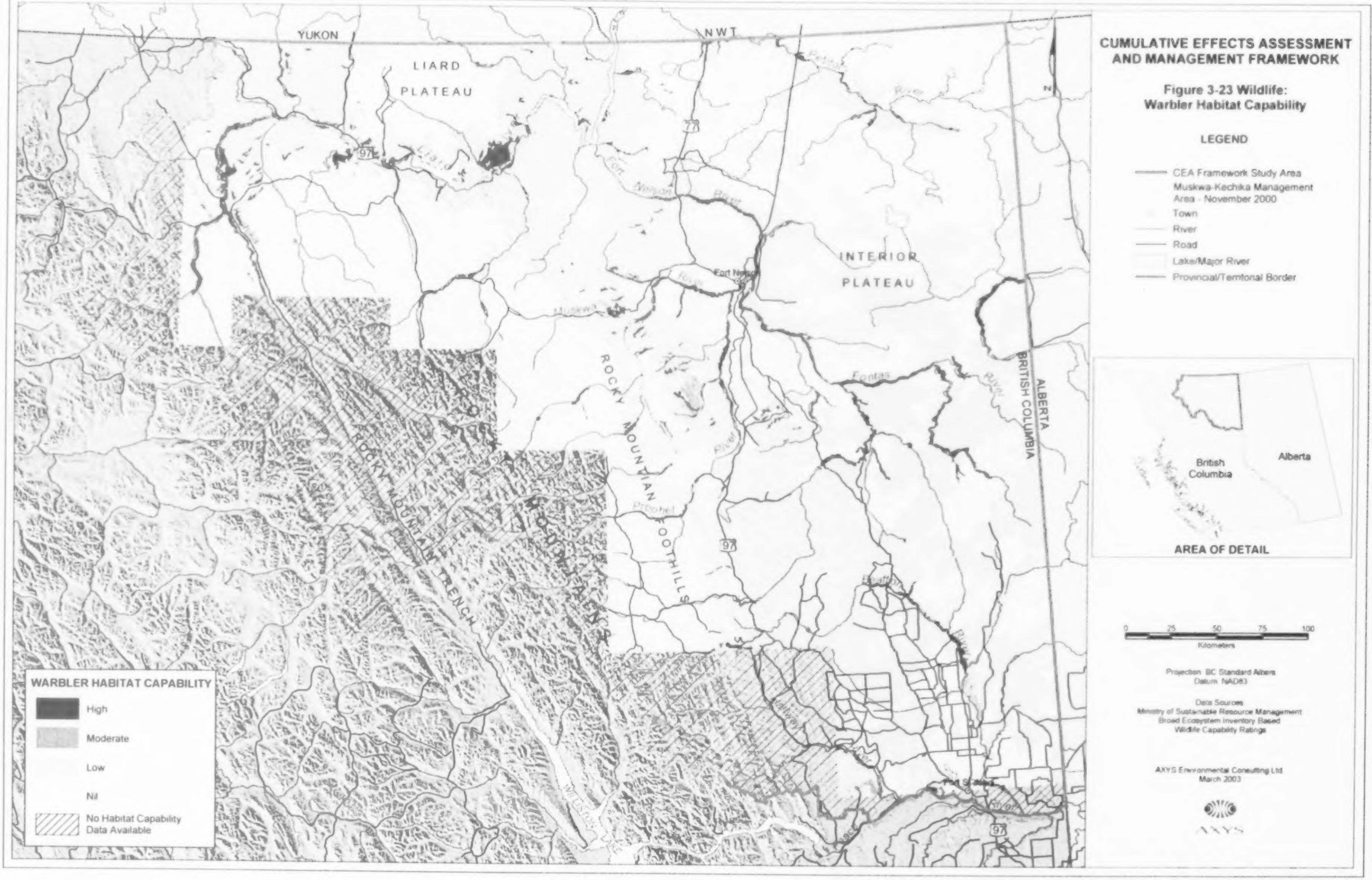


CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-22 Wildlife: Marten Habitat Capability



CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-23 Wildlife: Warbler Habitat Capability

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based
Wildlife Capability Ratings

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CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

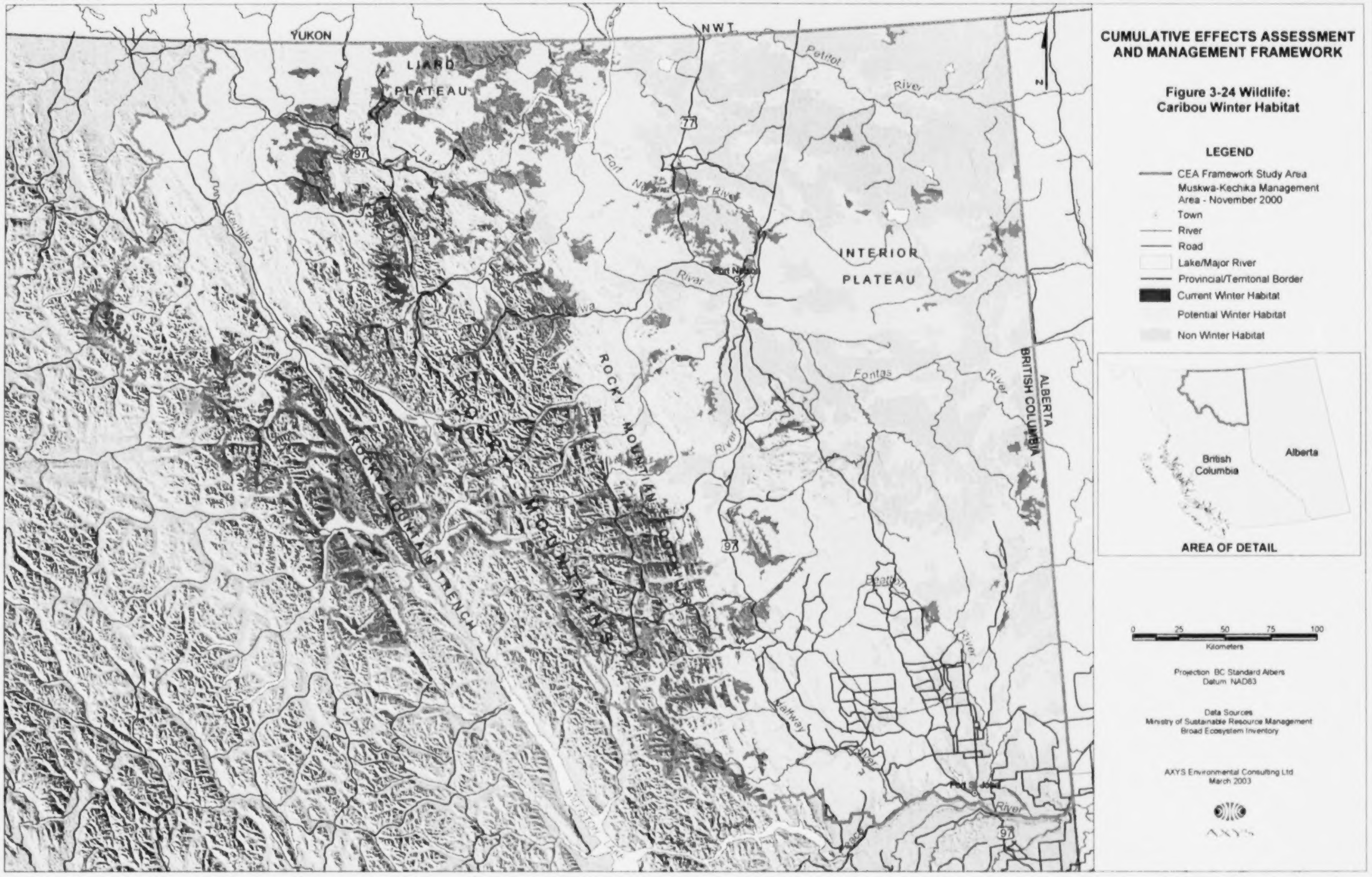

Figure 3-24 Wildlife: Caribou Winter Habitat

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory

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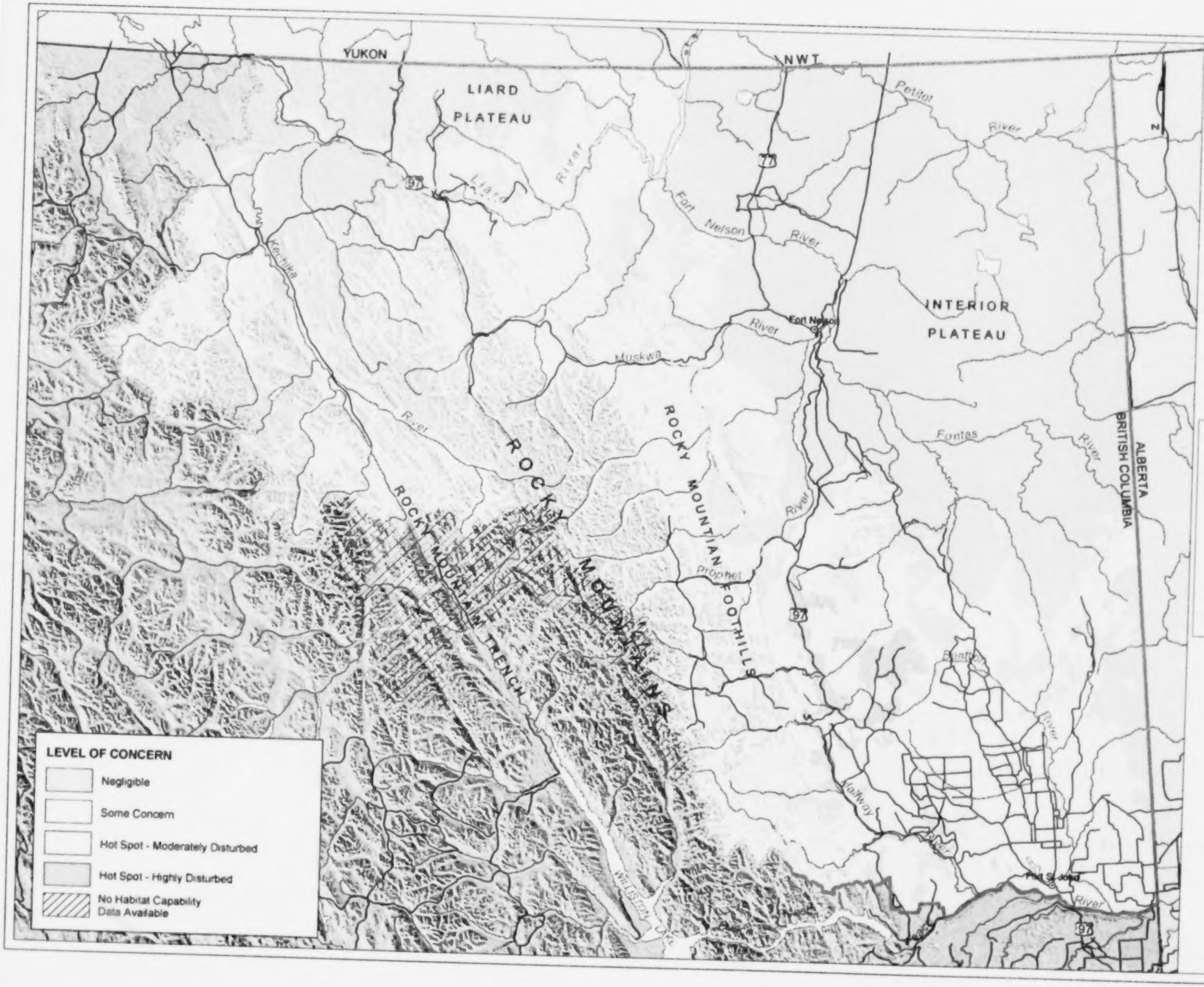
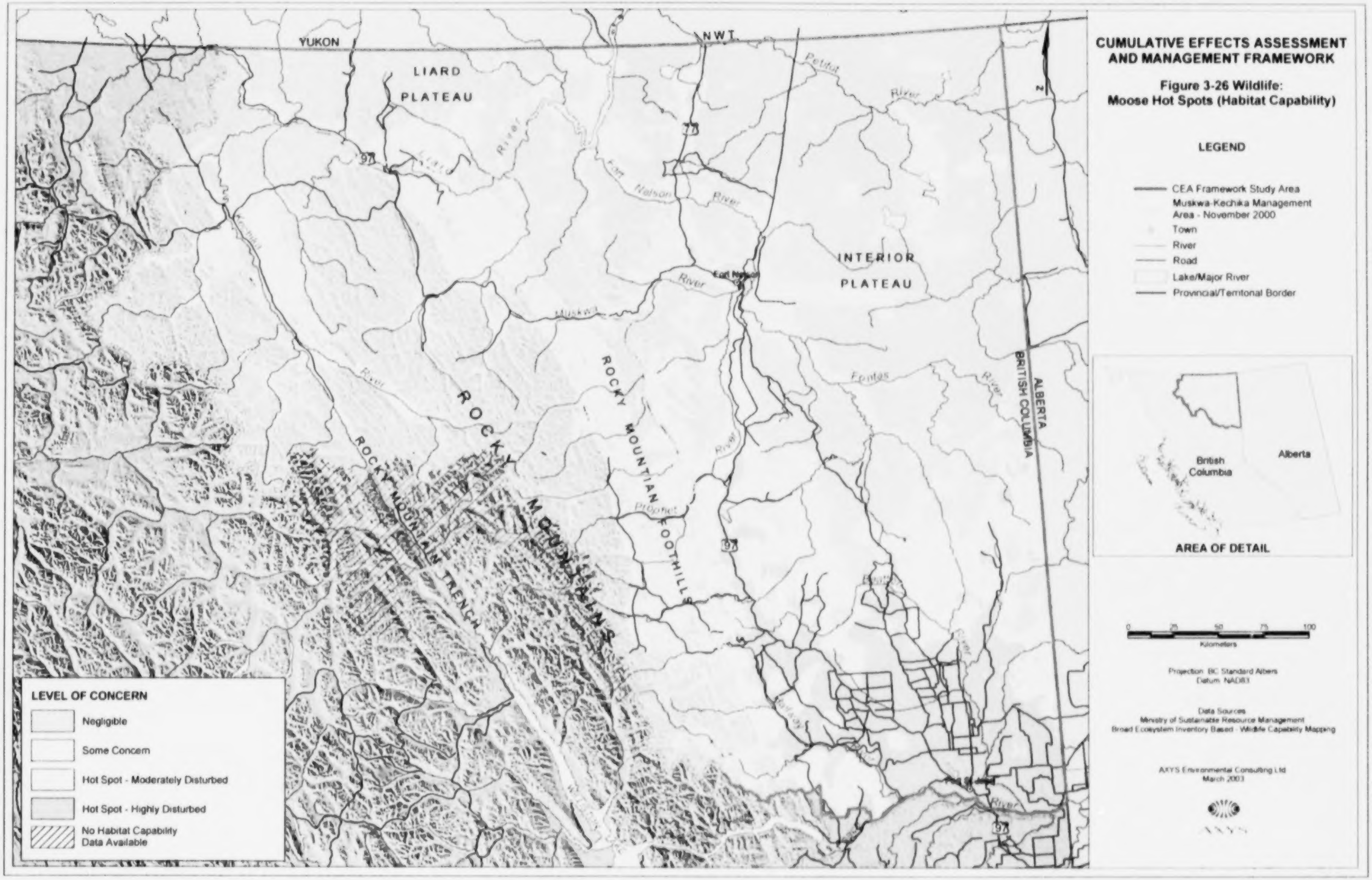
CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-25 Wildlife: Grizzly Bear Hot Spots (Habitat Capability)





CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-26 Wildlife: Moose Hot Spots (Habitat Capability)

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based - Wildlife Capability Mapping

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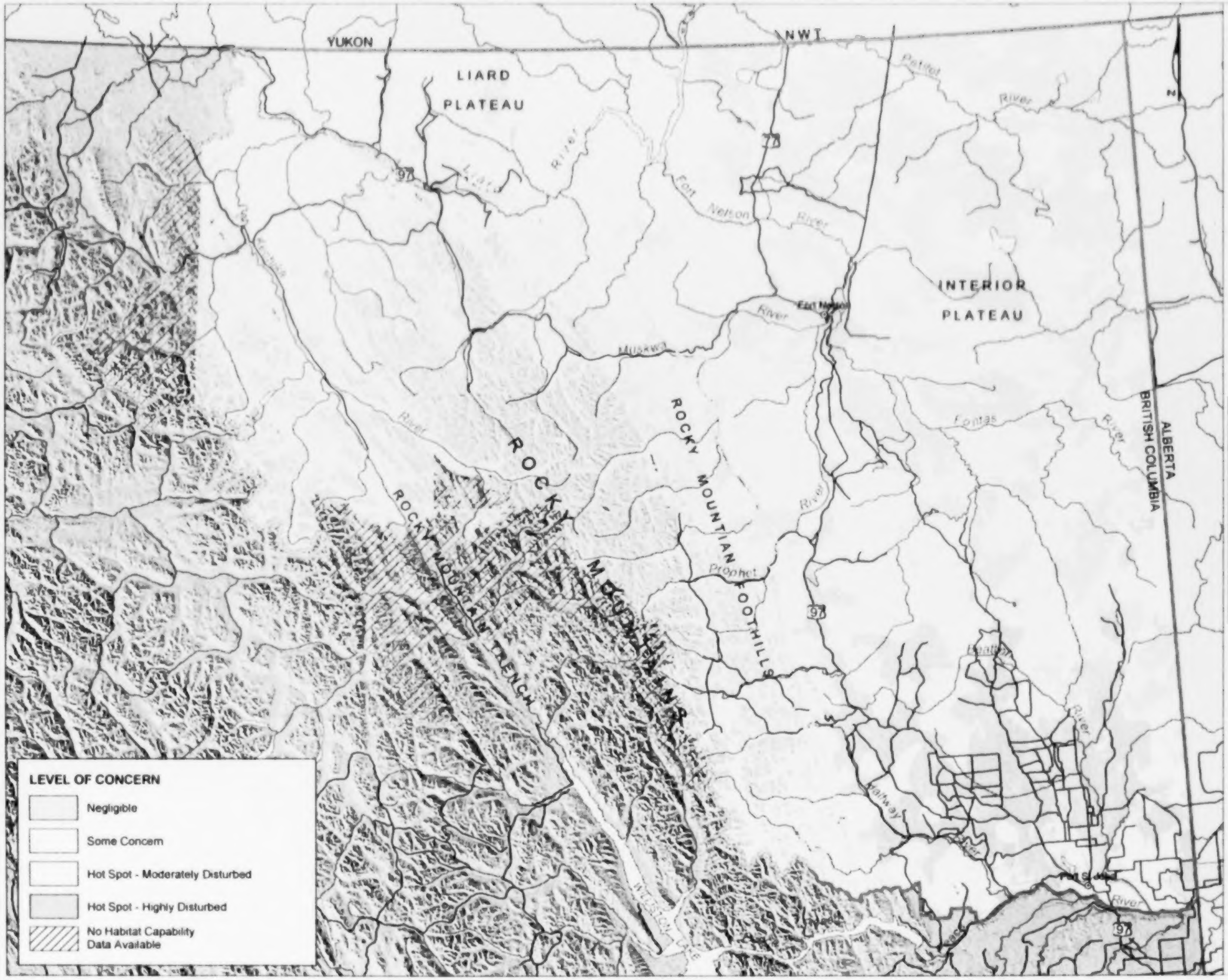
CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-27 Wildlife: Marten Hot Spots (Habitat Capability)



LEVEL OF CONCERN

- Negligible
- Some Concern
- Hot Spot - Moderately Disturbed
- Hot Spot - Highly Disturbed
- ▨ No Habitat Capability Data Available

LEGEND

- CEA Framework Study Area
- Muskwa-Kechika Management Area - November 2000
- Town
- River
- Road
- Lake/Major River
- Provincial/Territorial Border

AREA OF DETAIL

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based - Wildlife Capability Mapping

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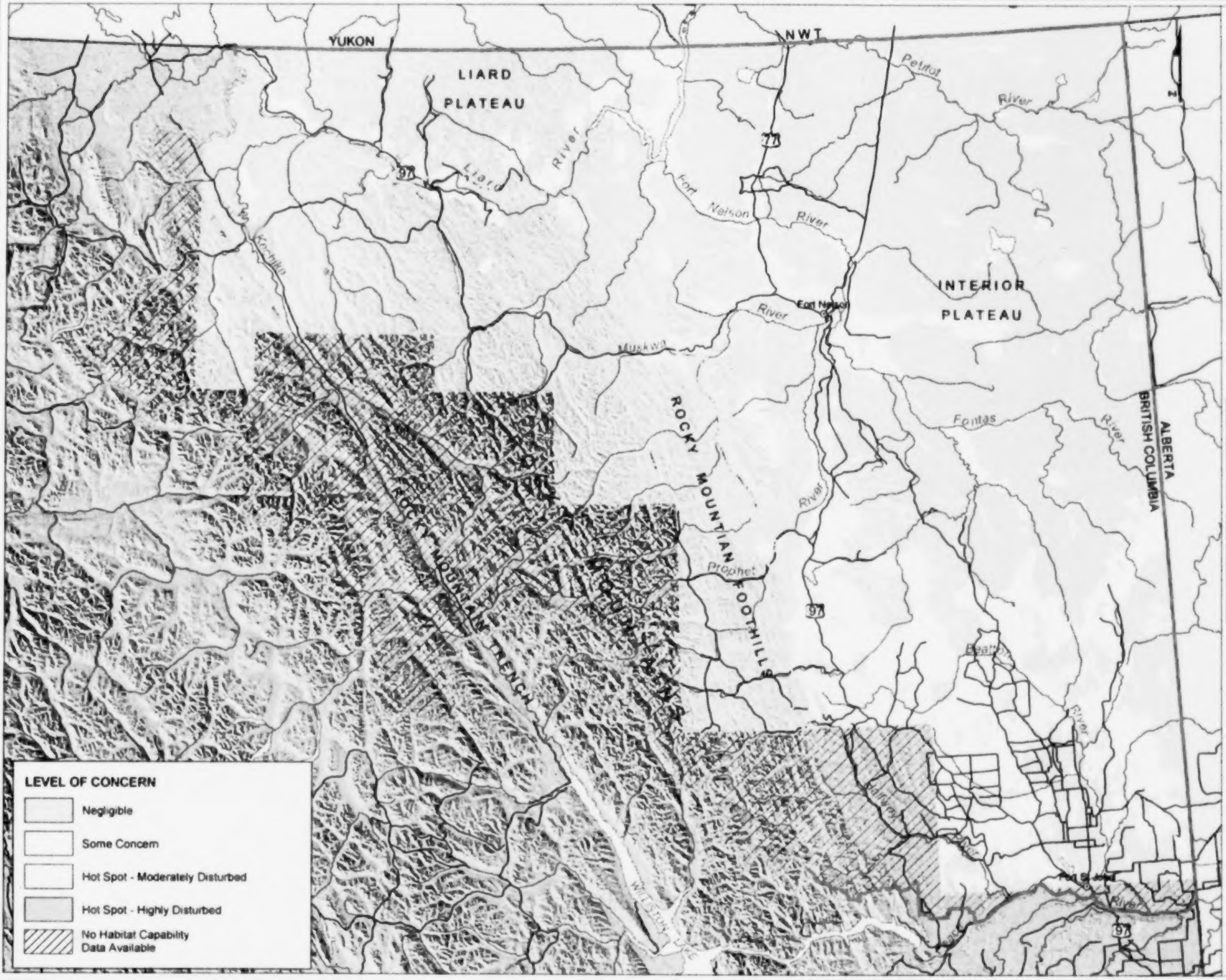

LEVEL OF CONCERN

- ☐ Negligible
- ☐ Some Concern
- ☐ Hot Spot - Moderately Disturbed
- ☐ Hot Spot - Highly Disturbed
- ▨ No Habitat Capability Data Available

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure 3-28 Wildlife:
Warbler Hot Spots (Habitat Capability)

LEGEND

- CEA Framework Study Area
- Muskwa-Kechika Management Area - November 2000
- Town
- River
- Road
- Lake/Major River
- Provincial/Territorial Border

AREA OF DETAIL

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based - Wildlife Capability Mapping

AXYS Environmental Consulting Ltd
March 2003

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CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

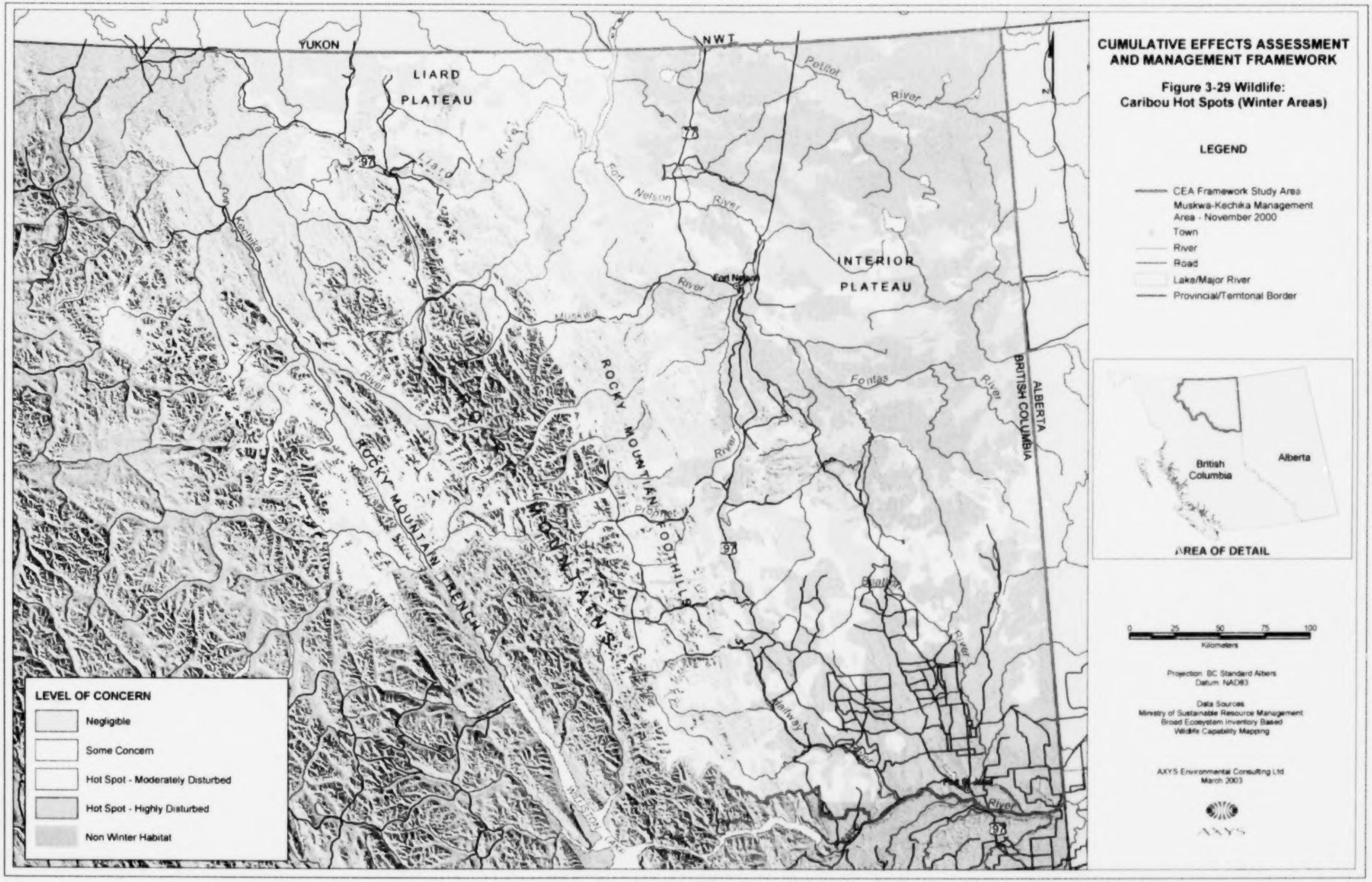

Figure 3-29 Wildlife: Caribou Hot Spots (Winter Areas)

Projection: BC Standard Albers
Datum: NAD83

Data Sources:
Ministry of Sustainable Resource Management
Broad Ecosystem Inventory Based
Wildlife Capability Mapping

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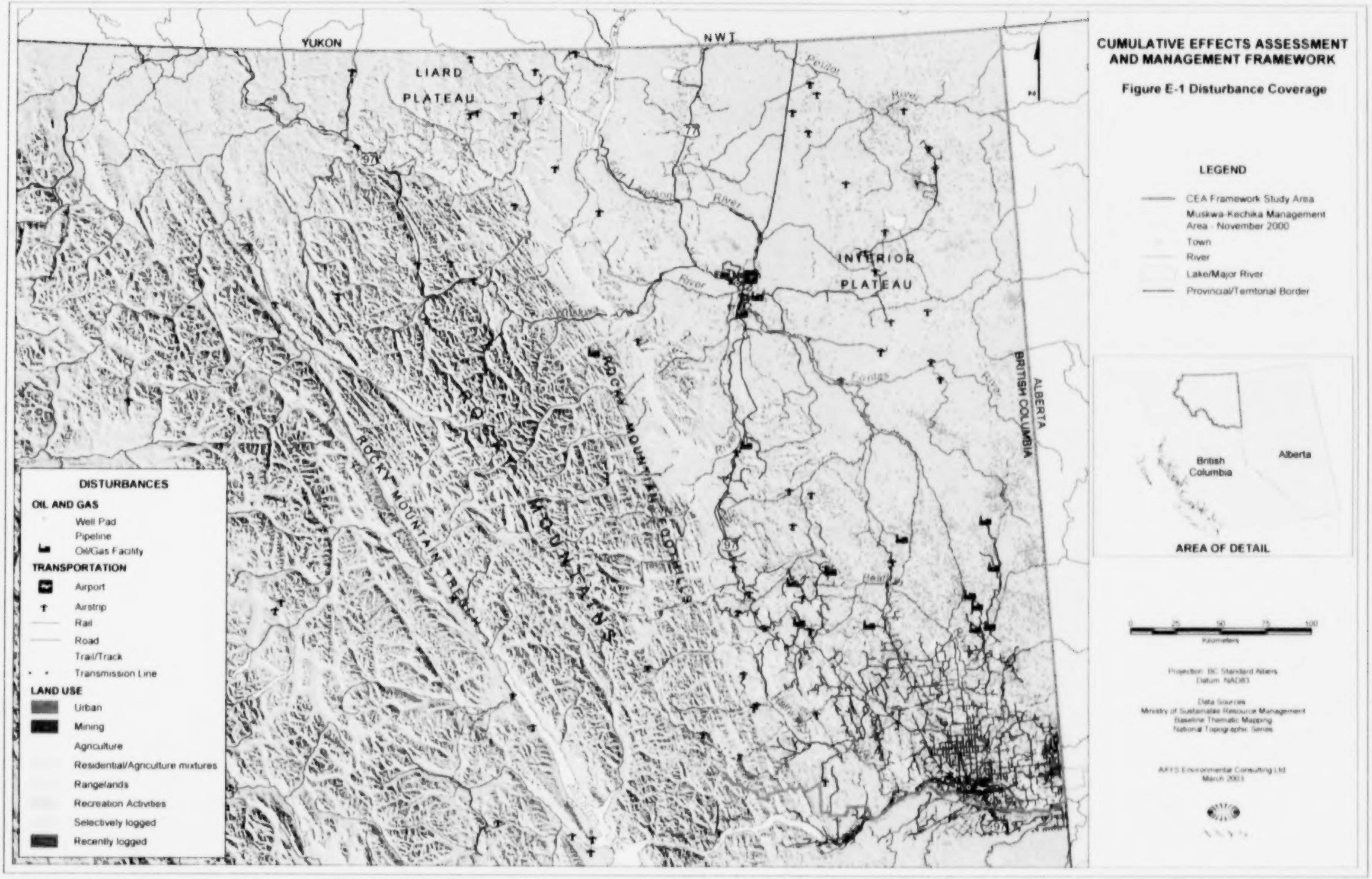

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Figure E-1 Disturbance Coverage

Projection: BC Standard Albers
Datum: NAD83

Data Sources
Ministry of Sustainable Resource Management
Baseline Thematic Mapping
National Topographic Series

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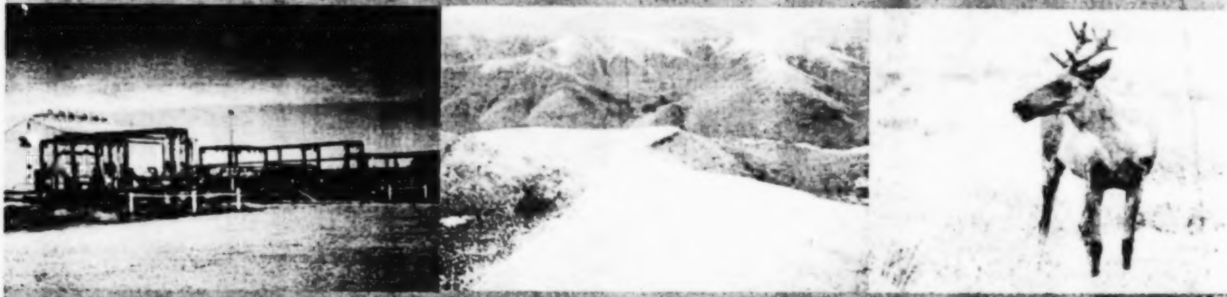
CEAMF STUDY: VOLUME 2

CUMULATIVE EFFECTS INDICATORS, THRESHOLDS, AND CASE STUDIES

FINAL



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MARCH 2003

PREPARED FOR: THE BC OIL AND GAS COMMISSION - THE MUSKWA-KECHIKA ADVISORY BOARD

Cumulative Effects Assessment and Management
for
Northeast British Columbia

Volume 2
Cumulative Effects Indicators, Thresholds, and Case Studies

Prepared by:

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March, 2003

EXECUTIVE SUMMARY

Cumulative effects are changes to the environment caused by the collective past, present, and future human actions; most result from the combined effects of simple, routine activities. There are four general types of cumulative effects: alteration, loss, and fragmentation of habitat; disturbance; barriers to movement; and direct and indirect mortality.

Management of cumulative effects is largely focused on defining where and how human activities can be continued without irreversible net harm to the environment. Thresholds (objective, science-based standards) based on ecological indicators can be used to evaluate the acceptability of both cumulative and project-specific effects. When properly derived and implemented, thresholds allow development activities to proceed without detailed review until the defined criterion is reached; at this point, additional review or regulation is initiated. To date, the best examples of thresholds are established air and water quality guidelines. For cumulative effects management, the most practical thresholds incorporate land-use and habitat indicators; these are being developed, but have not yet been widely applied on provincially-regulated lands.

To assess and manage cumulative effects in northeast British Columbia, we recommend the use of the following four complementary indicators:

- Land-use Indicators: Access Density, Stream Crossing Index
- Habitat Indicators: Core Area, Patch and Corridor Size

This report tested the applicability of various land-use and habitat indicators in the Blueberry and Sukunka study areas. Access density and core area size were both significantly related to moose and elk population indices in the Case Study areas; their predictive power was equivalent to that of more detailed and costly habitat indicators.

While road and trail density has been shown to be a practical cumulative effects indicator, results of the current Blueberry and Sukunka Case Studies suggest that previously published relationships between access density and large wildlife species may not apply directly to northeast British Columbia. This region has relatively low road and population densities, compared with other locations studied. As well, the intensity of road use is fairly low. In other areas, predators appear to select areas close to low-use roads, trails, and seismic lines while prey species appear to avoid them (presumably due to increased predation risk). This suggests that large predators may not be avoiding the physical feature the road represents, but rather the positive correlation between road density and number of encounters with humans.

A tiered threshold approach has been recommended since it provides a clear and integrated framework for derivation and implementation of ecological thresholds. With this approach, science-based and politically defined targets can be integrated with defined management actions so that operating rules are clear for all parties. As well, tiered thresholds provide the flexibility necessary for different land management regimes and ecological settings, and for a full spectrum of development proposals.

An implementation scheme for tiered thresholds is provided, using candidate access density and core area thresholds as examples. This implementation scheme is based on the existing resource management and review process and considers both project risk (i.e., simple, normal, complex) and land management regime (i.e., Land and Resource Management Plan Resource Management Zones) as a surrogate for acceptable change. Potential project-specific and cooperative management actions are related to these thresholds.

This information provides a foundation for threshold development and implementation but it is impractical to assume that this can immediately be applied to the entire region. The 'adaptive management' approach suggests that proposed management actions should be rigorously tested before they are widely applied.

The land use footprint in much of northeast British Columbia currently exceeds one or more candidate thresholds. Formal evaluations are recommended to allow government, industry, and other regional groups to understand the implications of threshold implementation and to ensure that derived thresholds provide an appropriate balance between environmental protection and economic development in the region. A variety of integrated management models, including the ALCES model tested in the Blueberry Case Study, are available for such evaluations.

Implementation will require agreement on definitions of acceptable change, threshold values, a standard public database, a standard process to calculate indicator values using this database, and project-specific and cooperative management actions to be implemented. The existing public database will need to be enhanced and made more readily accessible.

A pilot study is recommended to test the candidate thresholds and implementation process and ensure that they provide an appropriate balance between environmental protection and socio-economic interests, i.e., they reflect 'acceptable change' as defined by regional stakeholders. Stakeholders who will be affected by threshold implementation should be involved in designing and evaluating the pilot. This will allow the ecological, economic, and social implications of threshold implementation in northeast British Columbia to be explicitly considered.

Two areas are proposed for consideration: the Jedney Enhanced Resource Development Resource Management Zone in the Fort St. John Forest District, and the Etsho Enhanced Resource Development Resource Management Zone in the Fort Nelson Forest District. These are areas of ongoing interest from the petroleum and forest sectors that support boreal- and northern-ecotype woodland caribou. As demonstrated in the Case Studies, this species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance. Both areas have existing data that can be used to enhance our understanding of animal response to combined natural and human disturbance and to test management actions that will effectively and practically address cumulative effects.

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GLOSSARY

Access corridor – a linear feature created by humans (road, trail, pipeline, powerline, railway line, cutline) that may be used by pedestrians, vehicles, hunters, anglers, or animal predators.

ALCES – 'A Landscape Cumulative Effects Simulator' computer model used to forecast changes in landscape patterns and wildlife habitat. This simulator integrates four submodels (habitat availability, population, land use, and natural disturbance) and considers all land use activities likely to occur in the region. It includes both aquatic and terrestrial indicators and is able to incorporate random events such as fire.

Barrier – a barrier is present when it is not possible for animals to move across a corridor, and the habitat on either side of the corridor becomes isolated (e.g., a busy highway is a barrier for small ground-dwelling insects)

Biodiversity – the diversity of plants, animals, and other living organisms in all their forms and levels of organization (BCF and BCE 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Biogeoclimatic zone – a geographic area having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macro-climate (BCF and BCE 1995a).

Cautionary threshold – a threshold established to indicate that additional or more intensive monitoring is required to provide sufficient local data to confirm scientific predictions of both target and critical thresholds.

CEAM – Cumulative Effects Assessment and Management framework consisting of an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley; windrow, aeolian ridge) or as the result of human disturbance (e.g., roads, cutlines).

Critical threshold – a science-based target reflecting the continuous maximum amount of stress that a sensitive ecosystem or species can support without sustaining long-term harm. This may incorporate economic and social values to determine the acceptable magnitude of change, risk of long-term damage, or level of protection required.

Cumulative effects – changes to the environment caused by collective past, present, and future human actions; most result from the combined effects of simple, routine activities and projects.

DC – Disturbance Coefficient; an index assigned to each feature or activity type that rates the degree to which the disturbance zone of influence remains effectively useable by the species. Ratings are on a scale of 0 to 1 and are used to calculate habitat effectiveness.

Density-dependent – factors that affect population growth and parameters in relation to as animal abundance. These depress population growth as animal abundance increases, and increase growth as animal abundance decreases. Examples include food availability and quality. Predation may be density-dependent or –independent.

Density-independent – factors that affect population growth and parameters regardless of animal abundance. Examples include natural environmental disturbances such as fire, floods, or severe weather. Predation may be density-dependent or –independent.

Disturbance – a natural or human action that affects physical, chemical, or biological conditions.

Disturbance feature – a corridor or patch created by natural random events (e.g., burn or flood) or human action (e.g., cutblock, facility, community, road).

Disturbance trajectory – the calculated or predicted rate of natural or human disturbance.

Drainage - a subset of a watershed, generally less than 1,000 km^2 in size.

Early seral – forest that are younger than 40 years old (BCF and MELP 1999b).

Ecological resilience – the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996).

Ecological sink – an area with degraded habitat that has lower survival (or higher mortality) rates, causing local population declines. Although individual animals may continue to use this area, it creates a net loss to the population that may not be detectable for several generations.

Edge area - the area bordering patches and corridors where abiotic conditions (e.g., moisture, light, temperature, wind regimes) and biotic conditions (e.g., predation, mortality, competition, vegetation diversity and structure, species diversity and abundance) may be altered. Examples include the intersection between a cutblock and forest or a trail and native grassland.

Filter or porous barrier – a type of corridor across which some movement occurs but the rate of movement is less than through intact habitat (e.g., a busy highway is a porous barrier for large mobile wildlife like deer [*Odocoileus* spp.]).

Fragmentation – the process of losing habitat continuity through temporary or permanent conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). Three general effects result from habitat fragmentation: (1) original habitat is lost, (2) remaining habitat patches decrease in size, and, (3) patches become increasingly isolated from one another.

Habitat – the environment in which an organism or biological population lives or grows.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest regrowth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production; introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat availability – the amount of usable habitat accessible to a particular species.

Habitat capability – the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999).

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness for that species.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and regrowth is not allowed to occur (e.g., construction of a city, highway or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Habitat suitability – the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (RIC 1999).

Habitat unit – a defined terrestrial or aquatic unit with consistent abiotic and biotic conditions.

Hazard level – the risk of an adverse cumulative hydrological effect defined by the British Columbia Interior Watershed Assessment Procedure (IWAP; BCF and BCE 1995b, BCF 1999).

Human activity – all forms of human actions including land conversion and disturbance, damming, water withdrawal, pedestrian, vehicle and aircraft movements, harassment, harvest, and contaminant input.

Index or metric – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator – a surrogate measure used to represent or monitor the condition of an abiotic or biotic resource. May be a representative species, an outcome, or an input.

Interior area – also referred to as core area in this report. Interior areas are those beyond the influence of edge effects.

IWAP – Interior Watershed Assessment Procedure; a method developed by the provincial government to help forest managers understand the type and extent of current water-related problems in a watershed, and to recognize the implications of proposed activity in that watershed (BCF 1999).

Juvenile – an individual age 1 or older that has not reached maturity.

Landscape – an area of tens to hundreds of square kilometres that includes one dominant background ecosystem. Northeast British Columbia consists of a number of landscape types including the forest landscape, the agricultural landscape, and the alpine/subalpine landscape.

Local population - A breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Lowest observed effect level – concept from the field of ecotoxicology that represents the lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms compared to the controls. Also called lowest observed adverse effect level (LOAEL). This concept is also applicable to behavioural, physiological, and population response.

LU – Landscape Unit; an area of land and water used for long-term planning of resource management activities according to the *Forest Practices Code of British Columbia Act*. It may be used for designed strategies and patterns for landscape level biodiversity and for managing other forest resources (BCF and MELP 1999b).

LRMP – Land Resource Management Plan; a plan approved by the provincial government that establishes direction for land use and specifies broad resource management objectives and strategies.

Matrix – the dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Mature growth/mature seral – forests greater than a specified age (generally >80 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Metapopulation - a population of populations. This represents an abstraction of the population concept to a higher level. Metapopulations generally consist of a group of interacting but spatially discrete or isolated populations, subpopulations, or stocks. These subunits are linked by drainage networks but movement between subunits is infrequent and typically takes place across unsuitable habitat or over great distances (Hanski and Gilpin 1991; Dunham and Rieman 1999). An example of a fish metapopulation is a group of isolated headwaters populations found in the same watershed.

MSRM - British Columbia Ministry of Sustainable Resource Management

Natural disturbance type – an area characterized by a natural disturbance regime. The provincial government has established five natural disturbance types for managing biological diversity according to the *Forest Practices Code of British Columbia Act* (BCF and BCE 1995a; BCF and MELP 1999b).

OGC – British Columbia Oil and Gas Commission.

Old growth/old seral – forests greater than a specified age (generally >100 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches can occur naturally (e.g., sloughs, burns) or as the result of human disturbance (e.g., farmyards, wellsites, clearcuts).

Population – a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population limiting factors – processes that quantifiably affect the population rate-of-increase. Responsible for inducing year-to-year changes in animal abundance (Messier 1991).

Population regulating factors – density-dependent processes that ultimately keep populations within normal density ranges. These are a subset of limiting factors and predictably depress population growth as animal abundance increases (Messier 1991).

Reach – a defined watercourse channel section, tens to thousands of meters in length, with relatively consistent channel morphology, hydrology, and water chemistry.

Regional - an area more than hundreds of square kilometres that incorporates several landscapes.

Riparian - the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995c; BCF and MELP 1999b).

Riparian clearings - cleared areas within 15 m of a waterbody, including linear corridors, communities and residences, industrial and commercial facilities, cutblocks, and agricultural fields.

Riparian roads - roads and trails within 100 m of a waterbody.

RMZ – Resource Management Zone; defined subdivisions of an approved LRMP that have unique sets of resource values, objectives to maintain or enhance those values, and a number of strategies to be implemented to achieve those objectives. These provide geographically-focused, strategic direction (Fort St. John LRMP 1997).

Seral stage – the stages of natural ecological succession of a plant community, for example from young through mature to old stage (BCF and BCE 1995a).

Stream crossing - a road, trail, pipeline, powerline, railway line, or cutline crossing of a watercourse.

Subpopulation - a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Subwatershed - a subset of a watershed, generally less than 1,000 km^2 in size.

Target threshold – a politically-defined goal reflecting the optimum amount of stress on the system. This threshold is more protective than the critical threshold to provide a margin of safety. A target threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

Threshold – a point at which a resource changes to an unacceptable condition, with acceptability defined either from an ecological or social perspective.

Viable population – a self-sustaining population with a high probability of survival despite the foreseeable effects of demographic, environmental, and genetic stochasticity and of natural catastrophes (BCF and BCE 1995a).

Waterbody – a specific aquatic basins or channel (lake, pond, wetland, river, or stream).

Watercourse – a specific flowing channel (river or stream).

Watershed – a large drainage area, generally 1,000 to 10,000 km^2 in size, which flows directly into a large river such as the Peace River.

WHA – Wildlife Habitat Area contain critical habitat elements for one or more species of Identified Wildlife. These areas are mapped and approved by the Chief Forester and WLAP according to the *Forest Practices Code of British Columbia Act.*

WLAP – British Columbia Ministry of Water, Land and Air Protection.

ZOI – Zone of Influence; the distance to which a species is affected by an activity or disturbance.

SECTION 1: INTRODUCTION

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK ([illegible]F) STUDY

1. INTRODUCTION

To address the environmental effects associated with oil and gas development, the British Columbia Oil and Gas Commission (OGC) established an environmental fund for research projects. In 2001, cumulative effects was one of three research envelopes for which funding was provided.

1.1 CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Salmo Consulting Inc. (Salmo), Diversified Environmental Services (Diversified), AXYS Environmental Consulting Ltd. (Axys), and GAIA Consultants Inc. (Gaia) received funding to conduct three separate but integrated cumulative effects studies. Together, these studies provide an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia (hereafter referred to as Cumulative Effects Assessment and Management, or CEAM). The CEAM framework will ensure that cumulative effects are consistently addressed and managed as part of the OGC's ongoing project approval process.

The three components of the CEAM strategy are:

1. **CEAM Framework**: Development of an overall approach, specific to northeast British Columbia, for conducting project-specific and regional cumulative effects assessments. The framework will recommend:
    - approaches for scoping cumulative effects assessments (e.g., important regional issues, selection of indicators for ecosystem and socio-economic effects, setting spatial and temporal boundaries, identification of projects and human actions appropriate to consider in a CEA),
    - analytical approaches and tools (including management determination of impact significance),
    - mitigation approaches, and
    - follow-up and monitoring needs.

    As part of the CEAM framework, a spatial overview of existing cumulative effects in the Muskwa-Kechika Study Area (Figure 1) will be developed to identify potential areas of concern.

2. **Cumulative Effects Case Studies**: Detailed assessment of cumulative effects in two representative areas in northeastern British Columbia to demonstrate the application of the CEAM Framework with specific regional data. Project outputs will include:
    - a literature review on appropriate ecological indicators and thresholds for fish and wildlife management,

- a spatial database of existing biophysical and land use features for each representative area,
- a review of development and renewable resource trends for each representative area,
- the application of various methods and indicators to assess cumulative effects,
- identification of candidate thresholds for northeast British Columbia,
- recommendations on the use of these thresholds for cumulative effects assessment and management, and
- identification of implementation and data needs.

Information from the Case Studies will be used to modify and refine the CEAM Framework.

3. **Decision Support**: Decision support systems are valuable tools when evaluating competing land-use demands. They provide a systematic and consistent method for decision-making, as well as an audit trail. In the case of the OGC, the decision support system must allow rapid assessment of applications for a wide range of activities. This component will include:

    - developing and testing an application screening process for decision-making on cumulative effects management for petroleum exploration, development, and production proposals;
    - recommendations for establishing, managing, and updating regional databases; and,
    - recommended approaches for staff training.

    The decision support system will reflect the CEAM Framework and incorporate Case Study findings.

All three components will build from the results of existing and past initiatives such as Land and Resource Management Plans (LRMP), Forest Renewal BC policy, plans and studies, Ministry of Water, Land and Air Protection (WLAP) and Ministry of Sustainable Resource Management (MSRM) inventory and research, Muskwa-Kechika Trust Fund research, and ongoing research funded by the OGC.

1.2 CUMULATIVE EFFECTS CASE STUDIES

The Cumulative Effects Indicators, Thresholds, and Case Studies (Case Studies) component focuses on the Blueberry and Sukunka study areas in plateau and foothills habitat northwest and southwest of Fort St. John respectively (Figure 1). These areas were selected with the input of government, industry, and public stakeholders.

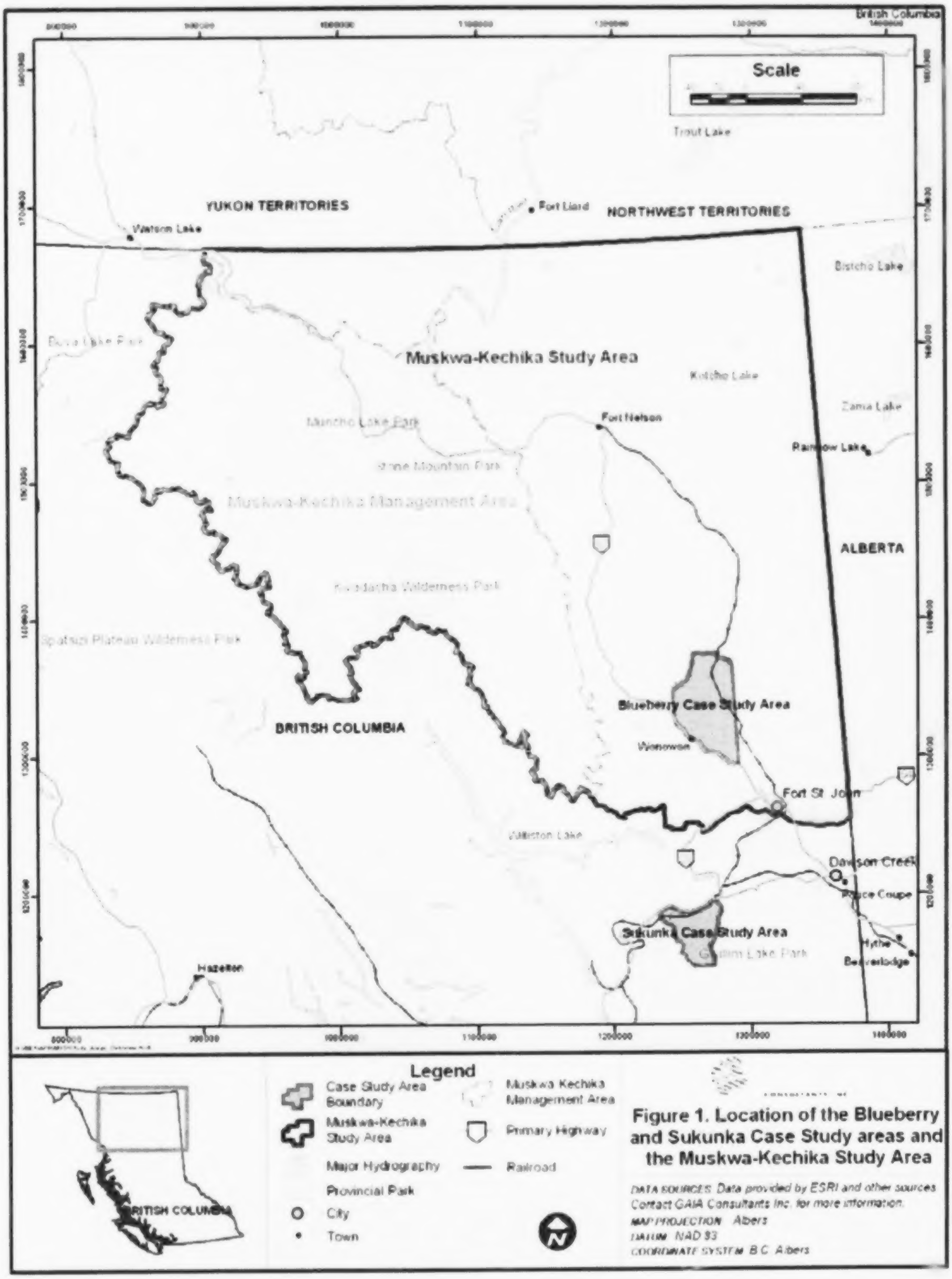


Figure 1. Location of the Blueberry and Sukunka Case Study areas and the Muskwa-Kechika Study Area

DATA SOURCES: Data provided by ESRI and other sources. Contact GAIA Consultants Inc. for more information.
MAP PROJECTION: Albers
DATUM: NAD 83
COORDINATE SYSTEM: B.C. Albers

1.3 REPORT OUTLINE

As follows, this report is divided into three main sections, with the detailed literature review and Case Studies in the appendices.

Section 2. Cumulative Effects Indicators for Northeast British Columbia

- identifies four candidate indicators for cumulative effects evaluation and management and explains the theory behind the choice of these indicators.

Section 3. Cumulative Effects Case Studies

- evaluates the applicability of the recommended cumulative effects indicators for OGC project-screening in northeast British Columbia using detailed regional data from the Blueberry and Sukunka Case Study Areas,
- summarizes the spatially explicit Geographic Information System (GIS) models that document existing development and biophysical features in the Case Study areas (details in Appendices 2 and 3),
- summarizes the cumulative effects analyses (applied using the CEAM framework) for the Case Study areas (details in Appendices 2 and 3),
- projects future land use and human activity patterns and possible renewable resource availability, abundance, and distribution,
- relates historical and projected renewable resource trends to land use and human activity patterns, and identifies apparent thresholds, and
- evaluates utility of existing data for use in cumulative effects assessments.

Section 4. Thresholds in Northeast British Columbia

- identifies proposed ecological thresholds for northeast British Columbia, and
- identifies a process to implement these thresholds and enhance cumulative effects management in northeast British Columbia.

Appendix 1. Cumulative Effects: Sources, Indicators, and Thresholds

- reviews cumulative effect concepts (i.e., alteration, loss, and fragmentation of habitat; barriers to movement; disturbance; direct mortality), and
- summarizes scientific literature on indicators and thresholds used in cumulative effects assessment.

Appendix 2. Blueberry Cumulative Effects Case Study

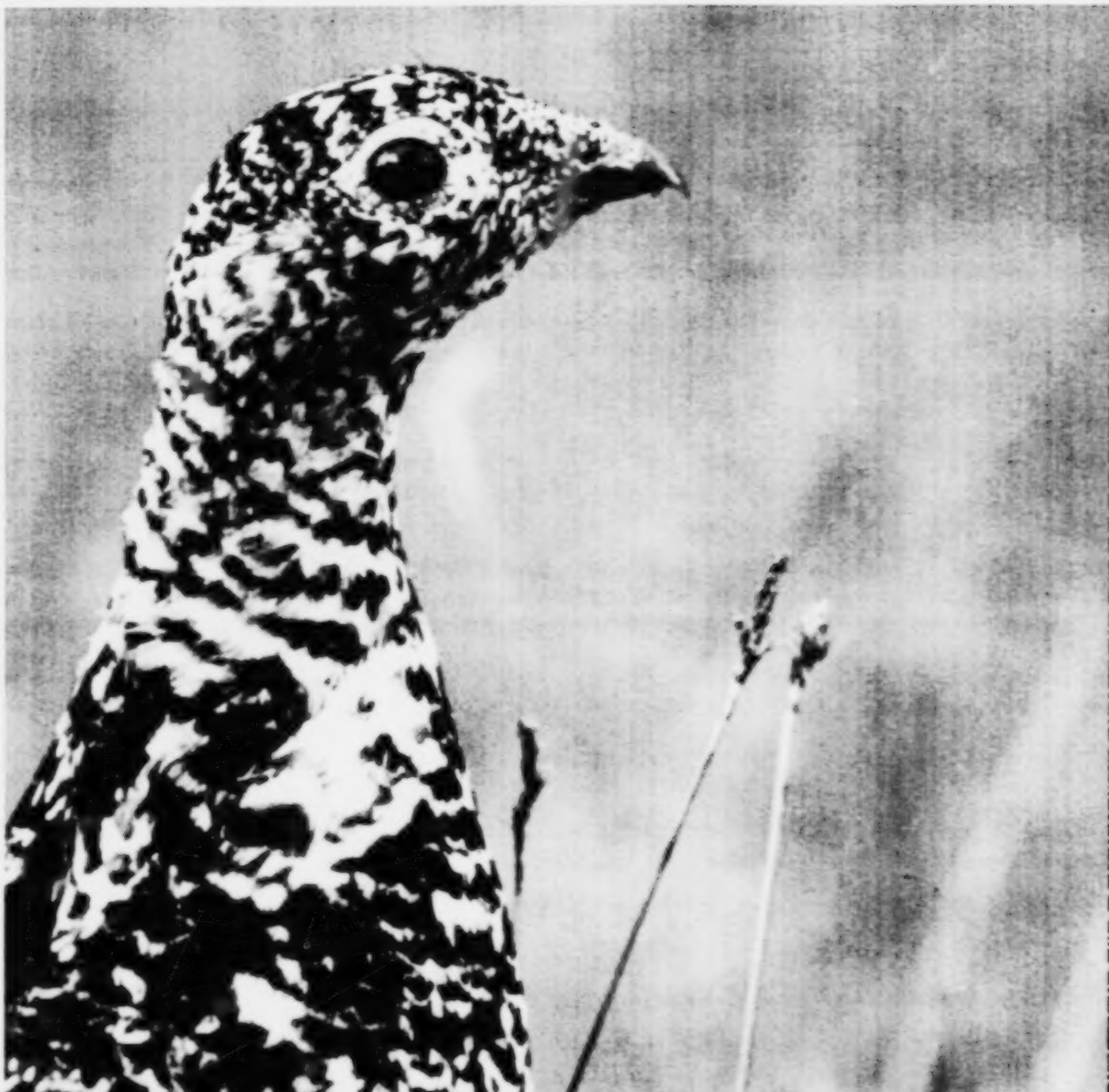
- provides a stand-alone Case Study report for the Blueberry area.

Appendix 3. Sukunka Cumulative Effects Case Study

- provides a stand-alone Case Study report for the Sukunka area.

SECTION 2: CUMULATIVE EFFECTS INDICATORS

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



2. CUMULATIVE EFFECTS INDICATORS FOR NORTHEAST BRITISH COLUMBIA

2.1 DEFINITION OF CUMULATIVE EFFECTS

Cumulative effects are environmental changes caused by combined past, present, and future human actions. Over the last twenty years, cumulative environmental effects have received increasing interest; it is now recognized that the combined effects of unrelated individual activities can be different in nature or extent from the sum of the effects of each individual activity (Contant and Wiggins 1991; FEARO 1994; Riffell et al. 1996).

In northeast British Columbia, cumulative effects result from direct loss and alteration of habitat due to petroleum exploration and production, forest harvest, agriculture and cattle grazing, recreational use; municipal, urban, and residential development, and other industrial activities. Indirect disturbance and wildlife harvest also occurs due to use of roads and trails by recreational and subsistence users (e.g., hunters, anglers). Cumulative effects can be classified into four types:

1. Habitat alteration, loss, and fragmentation,
2. Barriers to movement,
3. Direct and indirect mortality, and
4. Disturbance.

In some cases, the combined effect on a species or population of interest may be greater than would be expected by adding the individual effects. For example, livestock are attracted to wellsites, and cause trampling and increased spread of non-native and invasive species. This expands the total area of habitat loss and alteration beyond that attributable to petroleum production or grazing alone.

2.2 EVALUATING CUMULATIVE EFFECTS

Cumulative effects evaluation differs from conventional project-specific environmental assessment by considering larger geographic study areas, longer time frames, and all projects or activities that have been, or will be, carried out. Specific guidance for evaluation of cumulative effects in Canada is provided in FEARO (1994), CEAA (1996), Davies (1996), Hegmann et al. (1999), and AENV et al. (2000).

There are two main types of cumulative effects evaluations:

- **Resource management** studies consider the effects of all possible past, present, and reasonably foreseeable future disturbance sources (industrial, municipal, agricultural, domestic, recreational) over large geographic areas and long time frames (10-100 years). These regional studies normally gather available information, project future trends, and make management recommendations (e.g., Banff-Bow Valley Study 1996). To be most successful, regional assessments should include input from all interested stakeholders, and should be completed before human activities begin.

- **Project-specific** evaluations examine a proposed project in the context of other existing and likely disturbance sources; they are clearly the responsibility of the proponent. Potential combined effects are related to available environmental criteria to assess the significance of potential cumulative effects. Unfortunately, most proposed petroleum activities are located in areas currently lacking explicit cumulative effects criteria.

2.3 RECOMMENDED CUMULATIVE EFFECTS INDICATORS

In other areas, resource managers have concluded that a complementary suite of habitat and land-use indicators is the most practical and effective choice for cumulative effects assessment and management (Axys 2001b; BCC 2001). Land-use thresholds have been applied in the northwest United States for management of species at risk such as the grizzly bear (*Ursus arctos*) and spotted owl (*Strix occidentalis*; e.g., Lamberson et al. 1992; Mattson 1993; Bart 1995). In Canada, similar thresholds have been applied within national parks; research is underway to establish disturbance-based thresholds for grizzly bear and boreal-ecotype woodland caribou (*Rangifer tarandus*) in Alberta (Dugas and Stenhouse 2000; BCC 2001).

Indicators adopted for northeast British Columbia will be most effective when they are:

- based on management objectives identified in the Dawson Creek, Fort St. John, and Fort Nelson Land and Resource Management Plans (LRMPs),
- readily calculated, understood, and monitored,
- science-based, ideally using regional data,
- protective of fish and wildlife species of management and public concern,
- compatible with existing development review and assessment processes, and
- applicable to a wide range of ecological settings and development activities.

Table 1 identifies the suite of cumulative effects indicators recommended for northeast British Columbia based on the literature review included in Appendix 1.

Table 1. Recommended cumulative effects indicators.

Habitat Indicators	Land Use Indicators
Core Area	**Access Density** (km of corridors per unit area)
Patch and Corridor Size	**Stream Crossing Index** (number of crossings per km of stream)

The reasons for choosing these indicators will be explored in the following sub-sections. These indicators are tested against detailed regional data in the Case Studies (Section 3); Section 4 (Conclusions) presents candidate thresholds for these indicators.

2.3.1 Core Area, Habitat Indicator

Remaining **core area** is a widely used habitat index that quantifies the availability and location of areas with minimal human impacts. Core areas are relatively undisturbed, 'wilderness' areas and are often source areas for plant and animal populations or metapopulations.

Continuity of core areas is lost through natural disturbance or conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). This process is called **habitat fragmentation** (Collinge 1996; Jalkotzy et al. 1997). Three general effects result from habitat fragmentation (Figure 2):

- original habitat is lost,
- remaining habitat patches decrease in size, and
- patches become increasingly isolated from one another.

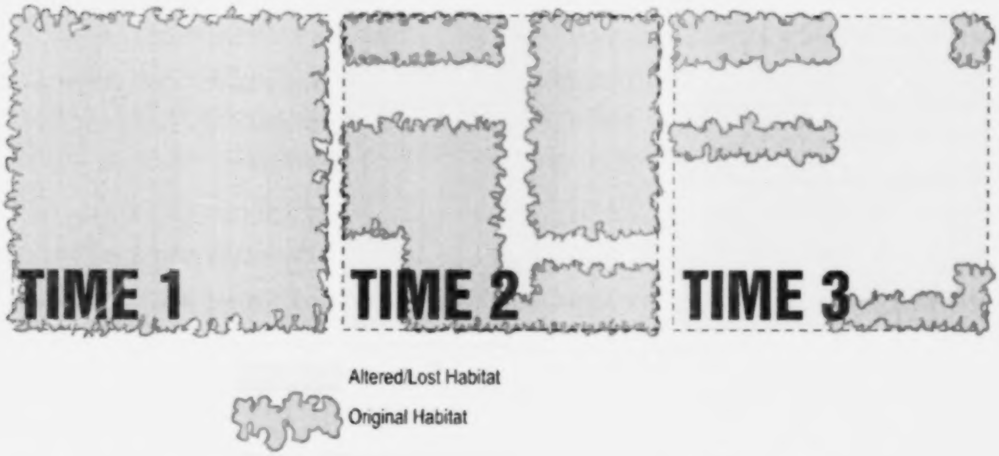


Figure 2. Representation of the habitat fragmentation process (adapted from Collinge 1996).

Core habitat is altered through **'edge' effects** at its boundaries when a new disturbance or corridor is introduced. Edge effects include altered microclimate, changes in habitat type and quality, altered predation patterns, and altered competition between species. Edges are particularly noticeable in forested landscapes, because of their dominant vertical structure. As fragmentation proceeds, edges between the patches and surrounding habitat increase in length and extent.

As depicted in Figure 3, edge effects are more pronounced in small or narrow patches. In very fragmented landscapes, all remaining habitat may be so close to an edge that no functional core habitat remains. As fragmentation proceeds, plants and animals that require core habitat are more likely to be affected than those with more flexible habitat needs.

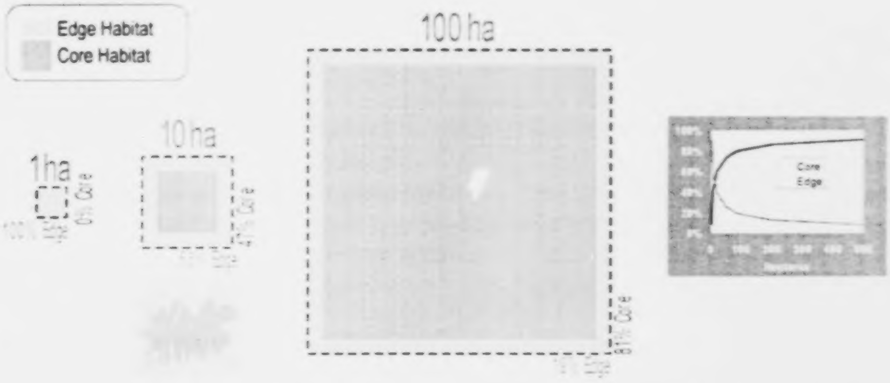


Figure 3. Relationship between patch size and edge area assuming 50 m edge width (adapted from Collinge 1996).

Core areas can be critical for population persistence in fragmented landscapes; conservation of these areas can be required to protect certain species (e.g., grizzly bear). Table 2 presents some examples of established core habitat guidelines.

Table 2. Examples of established core area guidelines.

	Guideline or Threshold	Comments
Core Area	>60% of available habitat as core area (Gibeau 2000).	Grizzly bear management threshold for Banff National Park.
	58 - 68% of available land as core areas (NCGBRT 2001).	Recommendation for grizzly bear recovery in the North Cascades of British Columbia.
	>60% of Forest Planning Area as roadless core wildlife habitat (Horejsi 1996).	Grizzly bear management recommendation for Yukon Territory.
	>40% of landscape in suitable habitat for habitat specialists such as interior forest songbirds (Wilcove *et al.* 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995).	Theoretical threshold based on modelling.
	Boreal-ecotype caribou populations declined when core area <50%; trend line identified threshold at <60% core area (Francis et al. 2002).	Threshold based on review of Alberta population data; used 250 m buffer from all linear features.
	>10 to 30% of landscape in suitable habitat for birds and mammals (Andren 1994).	Threshold based on review of Alberta population data, used 250 m buffer from all linear features.

2.3.2 Patch and Corridor Size, Habitat Indicator

Patches and corridors are reasonably uniform areas and linear features that differ from their surroundings. There are two main landscape types in northeast British Columbia. In the **forest landscape** (Figure 4), there are treed patches of variable size, age, structure, and species composition. Unforested openings associated with waterbodies, bedrock, and low-growing vegetative cover are also present. Within this matrix, there are human-disturbed patches such as wellsites and cut blocks, as well as disturbance corridors like roads, trails, and powerline and pipeline rights-of-way. The landscape outside forested areas (the **agricultural landscape**, Figure 5) is a human-dominated matrix with remnant areas of native trees, shrubs, and grasses in patches and along corridors (e.g., windrows or along road ditches).

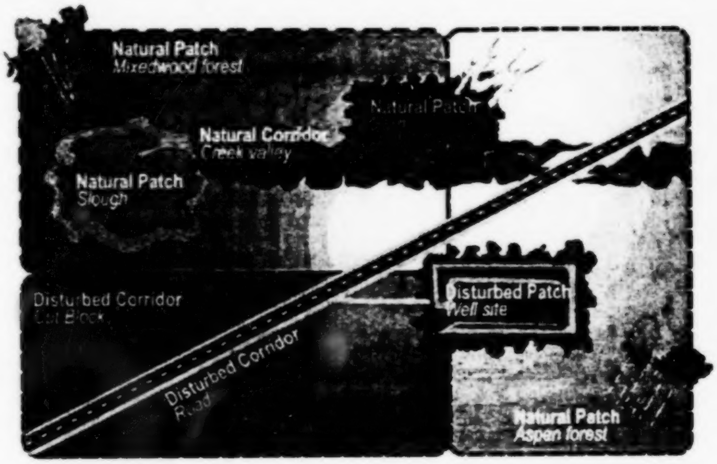


Figure 4. Patches and corridors within a forest landscape.

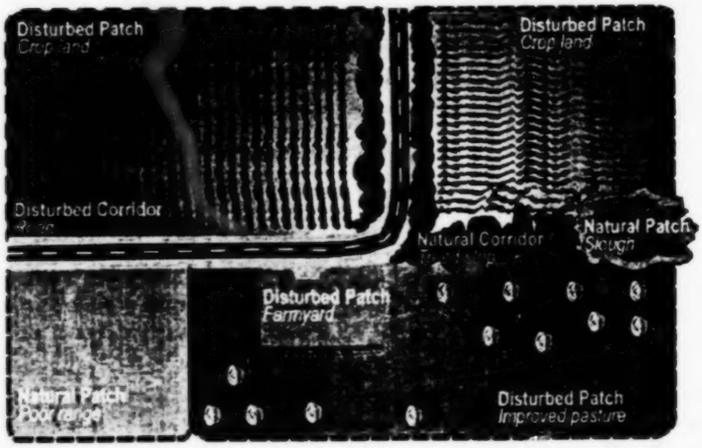


Figure 5. Patches and corridors within an agricultural landscape.

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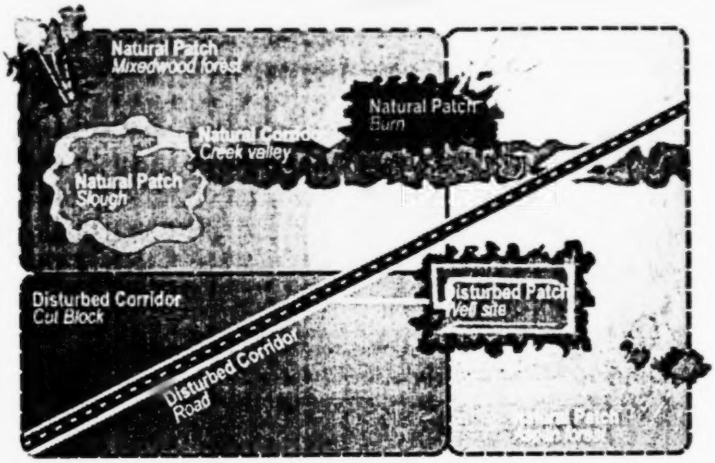

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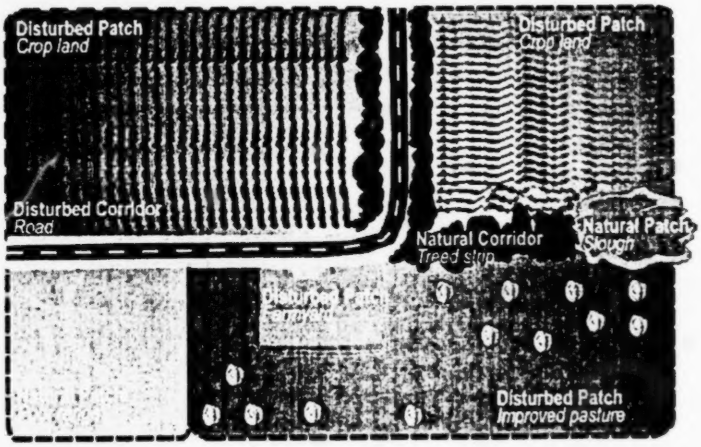

Figure 5. Patches and corridors within an agricultural landscape.

Cumulative effects occur where areas immediately adjacent to human-disturbed patches and corridors are used differently from nearby areas of identical habitat by individuals or species. This change in **'habitat effectiveness'** can accumulate over time and lead to reduced biodiversity and species abundance. In general, impacts are inversely related to the level and predictability of human disturbance. Unpredictable high-intensity activities (e.g., motorized snow machines, powerboats, gun shots) cause greater response than low intensity continuous activities (e.g., generator motor noise). Response of hunted animal populations is normally greatest. Animals may habituate to repeated or predictable disturbance that is perceived to be nonthreatening, lessening the loss of habitat effectiveness. However, as noted in Appendix 1, specific responses vary, and are complicated by many factors.

The shape of patches and corridors determines the amount of core habitat vulnerable to edge effects. Long, thin rectangles, like roads and cutlines, create more edge per unit area than other man-made features (Figure 6). As a result, they can have dramatic impacts on habitat effectiveness.

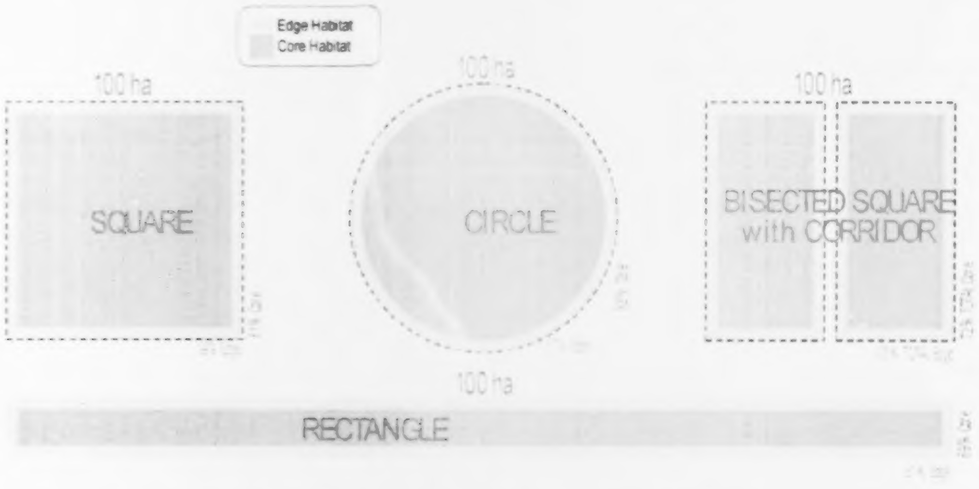

Figure 6. Relationship between patch geometry and edge area assuming 50 m edge width (adapted from Collinge 1996).

Corridors (and patches) can contribute to cumulative effects when animals are reluctant or unable to cross them. In general, the likelihood and magnitude of barrier effects increases as corridor width increases, the corridor becomes more dissimilar from surrounding habitat, and vehicular and human use of the corridor increases. A **barrier** is present when no movement occurs across a corridor and the habitat on either side of the corridor becomes isolated (e.g., an improperly constructed road culvert). If some movement occurs but the rate of movement is less than through intact habitat, then the corridor is considered a **filter** or **porous barrier**. The busy Alaska Highway would be considered a filter for large mobile wildlife such as deer but might represent a barrier for small ground-dwelling insect species.

Patch and corridor criteria can help define suitable habitat in fragmented landscapes. In the habitat fragmentation process, there appear to be 'critical thresholds' where rapid changes in patch size and isolation occur; criteria should reflect these critical thresholds. Table 3 presents some examples of established patch and corridor size guidelines.

Table 3. Examples of established patch and corridor size guidelines.

Indicator	Guideline or Threshold	Comments
Patch Size	>4.5 ha patch area for small and tolerant species (BCEAG 1999).	Based on literature review and local studies.
	Core area >10 ha in size, ideally >1,000 ha (NCGBRT 2001).	Recommendation for grizzly bear recovery in the North Cascades of British Columbia.
	Grizzly bear WHA security areas 1-500 ha; WHA foraging areas 5-250 ha (BCF and MELP 1999a).	Recommended British Columbia threshold; calculation method provided.
	Minimum patch size for 7 interior bird species ranged from 23 ha to 650 ha (Askins et al. 1987).	Based on studies in eastern mixedwood forest.
	>40 ha of suitable habitat in patch for persistence of black-throated green warbler (*Dendroica virens*; Hannon 1992).	Based on studies in central parkland of Alberta.
	>100-200 ha of suitable habitat in a patch for marten (*Martes americana*; Buskirk and Ruggiero 1994).	Based on literature review.
	200 ha undisturbed area for bull trout (*Salvelinus confluentus*; BCF and MELP 1999a).	Recommended British Columbia core area.
	Minimum core security area of 450 to 1,000 ha (Gibeau et al. 1996).	Grizzly bear core area used in western Canadian analyses based on 24 to 48 hour feeding bout of an adult female grizzly bear.
	>1,000 ha patch area for carnivores and sensitive species (BCEAG 1999).	Based on literature review and local studies.
Corridor Width	>200 m corridor width for moose (*Alces alces*; Nietfeld et al. 1985).	Based on literature review.
	>350 m corridor width for all species (BCEAG 1999).	Based on literature review; can be adjusted using prescribed formula to reflect security provided by vegetation and topography (BCEAG 1999).
	>600 m width for interior forest habitat conditions to be present (BCF and BCE 1995a).	Recommended British Columbia guideline.

2.3.3 Access Density, Land-Use Indicator

Road density is the best known and most widely applied land-use and access density indicator. This index represents the total length of roads, utility corridors (pipelines, powerlines, railway lines) or other human linear features present in a defined land area or watershed, and is usually expressed as km/km^2. It is a useful summary index because it integrates the many ecological effects of roads and vehicles (Forman and Hersperger 1996).

Roads are a very specific type of corridor. As long, narrow linear features, they create a very high edge per unit area (Figure 6). Thus, they can have dramatic impacts on the effectiveness of adjacent habitat. As well, the habitat occupied by the roads is temporarily or permanently lost. If the road is eventually reclaimed and allowed to revegetate, the habitat loss is temporary; permanent habitat loss may occur with public roads like highways.

Roads are of increasing concern for terrestrial and aquatic communities because research indicates that some animals under-use areas adjacent to active roads. Figure 7 depicts road-habitat effectiveness models developed for a hunted elk (*Cervus elaphus*) population; habitat effectiveness is inversely related to road density.

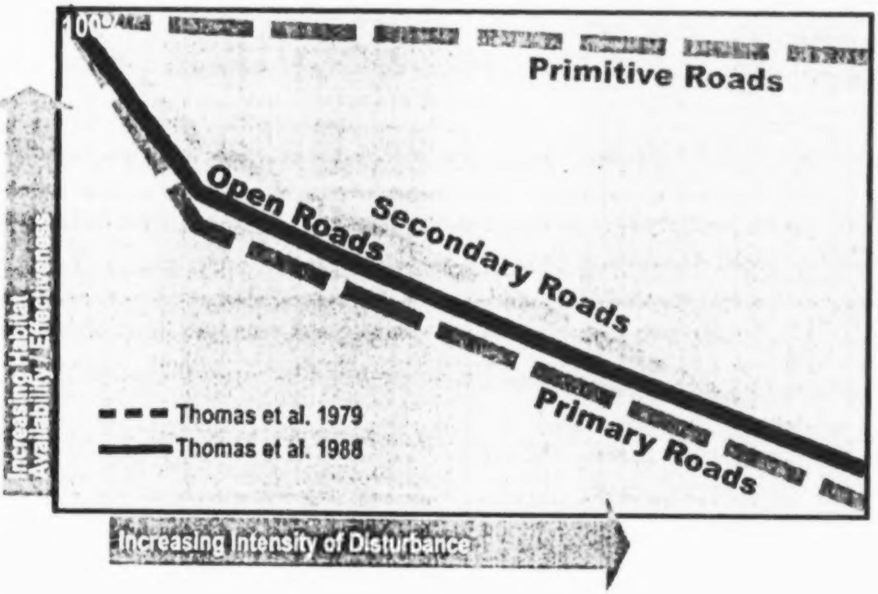

Figure 7. Impact of roads on predicted habitat effectiveness for elk (adapted from Thomas et al. 1979, 1988).

Figure 7 also illustrates the effect of disturbance intensity on habitat effectiveness. 'Open roads' is a summary class that includes all road types and is assumed to represent the average effect. Infrequently used access features like 'Primitive Roads' (truck trails) affect elk habitat use considerably less than more regularly used Primary and Secondary powerlines, railway lines) or other human linear features present in a defined land area or watershed, and is usually expressed as km/km^2. It is a useful summary index because it integrates the many ecological effects of roads and vehicles (Forman and Hersperger 1996).

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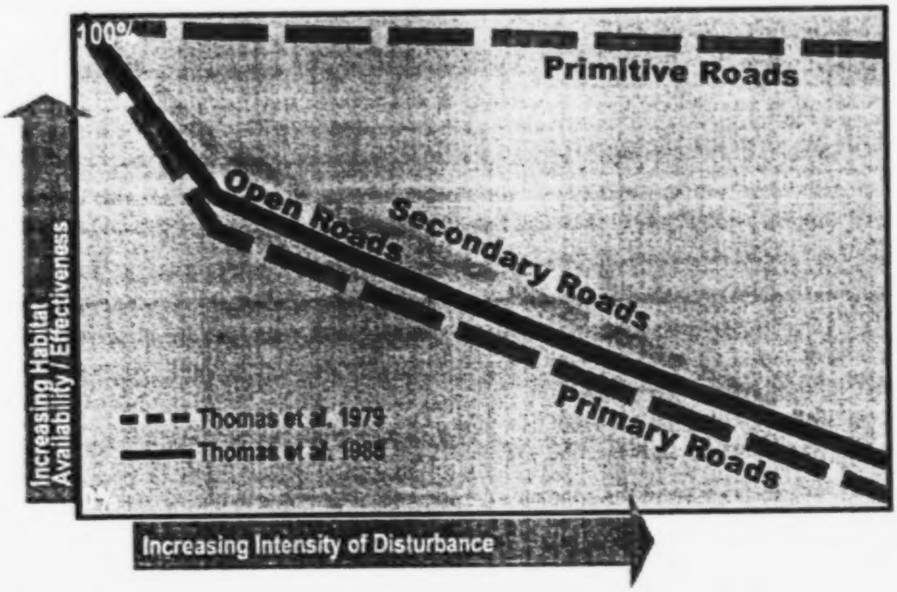

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Roads. This suggests that activity levels, rather than the roads themselves, are affecting the use of this habitat by local wildlife. The impact of cutlines and utility corridors (pipeline and powerline rights-of-way) may be lower since these features receive less human use, especially in lightly populated regions like northeast British Columbia. However, all types of linear corridors may increase predation rates by providing travel routes for wolves (*Canis lupus*), thereby increasing their search range and efficiency (Bergerud et al. 1984; Stuart-Smith et al. 1997; James and Stuart-Smith 2000). There is currently substantial debate on other effects (e.g., habitat fragmentation) associated with cutlines and utility corridors.

Access corridors can contribute to cumulative effects by increasing direct and indirect mortality rates. Primary and secondary roads can substantially increase vehicle collisions and direct mortality rates. All types of linear corridors can provide access for hunters and anglers, leading to increased harvest effort and success. These indirect mortality effects are difficult to manage (Mychasiw and Hoefs 1988; Trombulak and Frissell 2000). In addition, there is a tendency for roads and trails to be extended beyond their original destination, ultimately creating a permanent access network.

Increased road and trail density is related to increased sediment transport and peak flows in streams, and has been correlated with declines in trout and salmon species, including bull trout (*Salvelinus confluentus*; USDA 1996; Rieman et al. 1997). Fish populations in areas accessible by roads may be more vulnerable to introductions of non-native species that can displace or replace native species (Baxter et al. 1999; BCF 1999). Table 4 provides some examples of established road and corridor density guidelines and thresholds.

2.3.4 Stream Crossing Index, Land-Use Indicator

The stream-crossing index is an easily calculated measure of sediment and mortality sources and stream habitat fragmentation in a watershed. It is expressed as the number of road, trail, utility corridor, and cutline crossings per kilometre of stream. A watercourse that is repeatedly crossed is more likely to suffer increased erosion and water temperature, have higher angling pressure, and have temporary or permanent barriers to fish passage. Table 5 provides an example of an established stream crossing index guideline.

Table 4. Examples of established access density guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Road and Trail Density	- Road density <0.6 km/km^2 to protect high quality grizzly bear habitat (BCF and MELP 1999a).	- Recommended British Columbia threshold.
	- Density of calving barren-ground caribou highest at road density of 0 km/km^2 and declined by 86% at road densities >0.6 km/km^2; male and yearling density highest at 0.3-0.6 km/km^2 (Nellemann and Cameron 1998).	- Based on studies in Alaska petroleum development areas.
	- Road densities <0.6 km/km^2 in winter range used by northern-ecotype caribou range (Salmo unpub. data).	- Based on studies in west central Alberta.
	- Watersheds with >1 km/km^2 road density had degraded bull trout habitat (Craig 2001).	- Based on studies in Yakima River basin.
	- Grizzly bears selected areas with mean road densities of 0.6-0.68 km/km^2; areas with road densities >6 km/km^2 did not support grizzly bears (Mace et al. 1996; McLellan and Hovey 2001).	- Based on studies in northern Montana and southeast British Columbia.
	- Road densities >0.6 km/km^2 affect habitat usage by wolves and elk (Lyon 1983, 1984; Thiel 1985; Mech 1989; Edge and Marcum 1991; Rowland et al. 2000).	- Effects can be mitigated by the presence of visual barriers and adjacent unroaded areas.
	- Road density <1.5 km/km^2 to protect bull trout (BCF and MELP 1999a).	- Recommended British Columbia threshold; additional site-specific work required beyond this point.
	- Bull trout populations seven times more likely to be strong in subwatersheds with road densities <1.55 km/km^2 (Rieman et al. 1997).	- Based on study in interior watersheds in Pacific Northwest United States.
	- Total weighted road density should be 0 km/km^2 in grizzly bear core areas (USFS 1993).	- Management goal for Idaho National Forest; total weighted road density considers hiding cover, level of use, and closure status to provide a common standard.
Corridor Density	- Boreal-ecotype woodland caribou populations declined when total corridors >1.8 km/km^2 (Francis et al. 2002).	- Threshold based on Alberta population data.
	- Boreal-ecotype woodland caribou populations do not persist when total corridors >3 km/km^2 (B. Stelfox pers. comm.).	- Threshold identified by caribou biologists in Delphi process.

Table 5. Examples of established stream-crossing index guidelines.

Indicator	Guideline or Threshold	Comments
Stream Crossing Index	- >0.4 stream crossings by roads per square kilometre indicates risk of cumulative effect (BCF and BCE 1995b). - <0.6 stream crossings by roads per square kilometre to protect bull trout (BCF and MELP 1999a).	- Part of the British Columbia Interior Watershed Assessment Procedure (IWAP). Stream crossing index is calculated by sub-watershed. - Recommended British Columbia threshold; additional site-specific work required beyond this point.

2.4 APPLYING THRESHOLDS

Indicators present information about the likelihood of adverse cumulative effects, but provide no direct measure of the acceptability of those effects. Thresholds are derived standards used to define the point at which a resource indicator changes from an acceptable to unacceptable condition.

A perceived advantage of thresholds is that they allow development activities to proceed without detailed review until the defined threshold is reached. In other words, if the incremental effects of a proposed activity do not cause the defined threshold to be exceeded, then effects are concluded to be insignificant and the proposed activity is typically viewed as acceptable. Once the threshold range is reached however, additional review or regulation becomes necessary (Ziemer 1994; Axys 2001a).

Tiered chemical thresholds are commonly used for assessment and management of air and water quality. This concept is also applicable to ecological thresholds and is recommended for northeast British Columbia since it provides a clear and integrated framework for threshold derivation and implementation. With this approach, science-based and politically defined targets can be integrated with defined management actions so that operating rules are clear for all parties.

Tiered thresholds implicitly recognize the uncertainty inherent in our understanding of complex ecological relationships. In doing so, they provide a framework to gather data on actual responses and modify management actions as appropriate. As well, tiered thresholds provide the flexibility necessary for different land management regimes and ecological settings, and for a full spectrum of development proposals.

In northeast British Columbia, project proposals are likely to undergo one of three types of regulatory review:

1. **Routine Review**: Simple proposals with limited potential for significant adverse cumulative effects.
2. **Enhanced Review**: Normal proposals in sensitive areas or those with some potential for significant adverse cumulative effects.

3. **Complex Review**: Complex proposals with high potential for significant cumulative effects

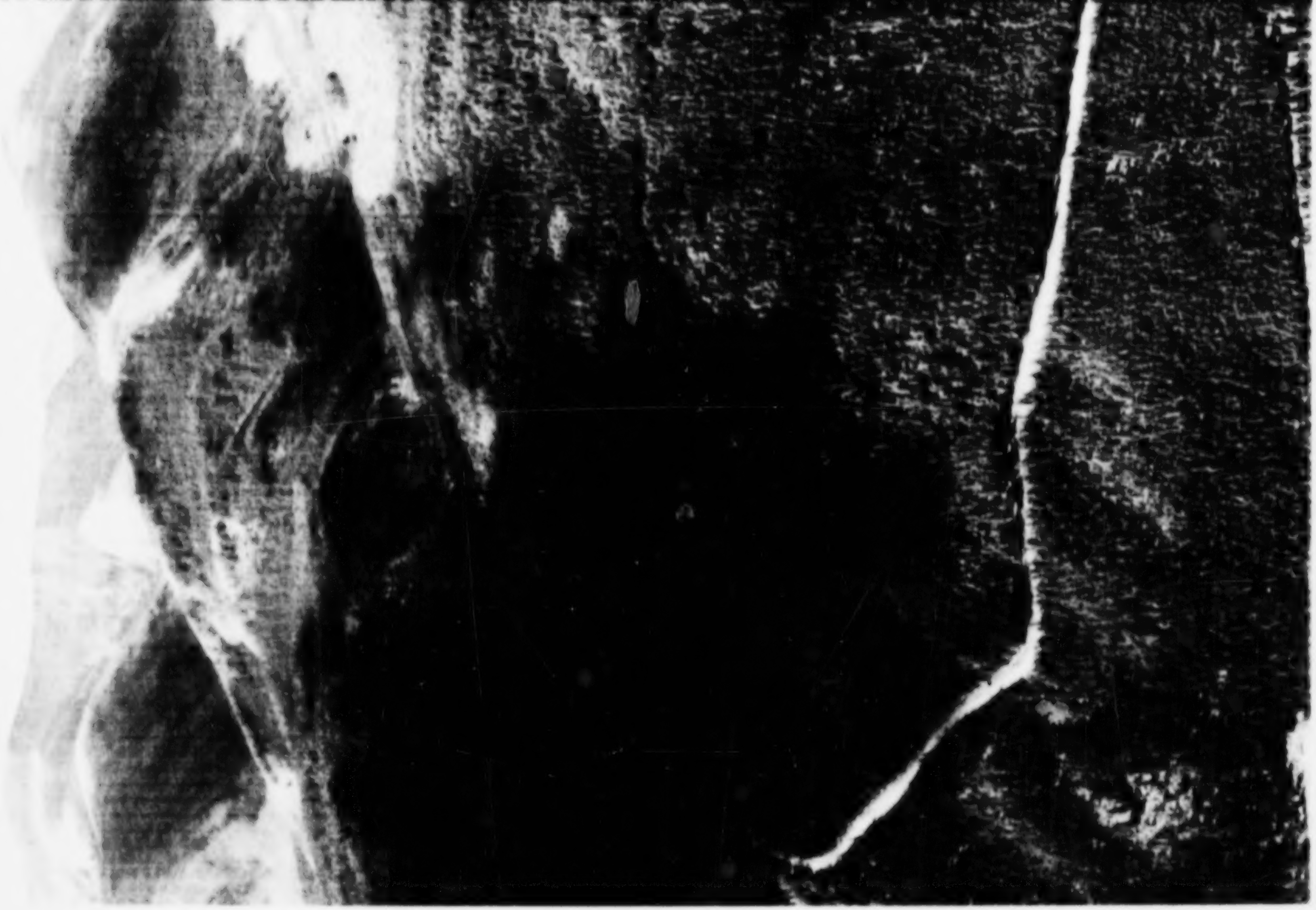
Table 6 summarizes desirable attributes of thresholds for each type of regulatory review. Further discussion of threshold application is provided in Section 4.

Table 6. Threshold attributes for different categories of regulatory review in northeast British Columbia.

Cumulative Effects Screening (Routine)	Cumulative Effects Evaluation (Enhanced)	Cumulative Effects Assessment (Complex)
• Uses generalized thresholds.	• Uses generalized and species-specific thresholds.	• Uses species- and RMZ-, LU-, or WHA-specific thresholds.
• Quickly and cheaply completed.	• Intermediate cost and lead-time.	• Highest cost and longest lead-time to complete.
• Uses readily available data.	• Site-specific data and field studies may be needed.	• Site-specific data and field studies required.
• Limited need for specialized expertise.	• Specialized expertise generally needed.	• Specialized expertise required.
• Easily measured and enforced.	• Measurable and enforceable.	• Most difficult to measure and enforce.
• Provides indirect measure of impacts.		• Provides direct measure of impacts.
• Examples: Maximum Access Density Maximum Disturbance Maximum Activity Level	• Examples: Maximum Open Road Density Maximum Mortality Rate Maximum Clearing on Unstable Slopes	• Examples: No Net Loss of Grizzly Bear Habitat Effectiveness No Net Fish Habitat Loss

SECTION 3 CUMULATIVE EFFECTS CASE STUDIES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK [illegible] STUDY



3. CUMULATIVE EFFECTS CASE STUDIES

Current and historical conditions were documented in two areas where petroleum development has occurred at different times and under different land management regimes. Resource Management Zones (RMZs) identified in approved Land and Resource Management Plans (LRMPs) were used as the basis for selecting case study areas to allow results to be applied to other areas of northeast British Columbia. The two areas selected were:

- Blueberry Case Study Area, included in the Jedney Enhanced Resource Development, Agriculture Settlement, Grazing Reserve, and Alaska Highway RMZs of the Fort St. John LRMP (1997): This 2,690 km^2 area is located northeast of the community of Wonowon (Figure 1), and is moderately to highly disturbed following more than 50 years of development. The area is characterized by rolling terrain, with mixedwood uplands and occasional black spruce (*Picea mariana*) muskeg; moose (*Alces alces*), caribou, furbearers, migratory songbirds, and Arctic grayling (*Thymallus arcticus*) are key species. The primary management objective for this area is to maintain or enhance resource extraction opportunities. Case Study boundaries were defined by the availability of historical air photographs and renewable resource data.
- Sukunka Case Study Area, included in the South Peace Enhanced Resource Management RMZ of the Dawson Creek LRMP (MEM et al. 1999): This 1,215 km^2 area is located southwest of Chetwynd (Figure 1), and is lightly to moderately disturbed following 30 years of development. The Sukunka area includes mixedwood and conifer forests on the Rocky Mountain foothills and front ranges; elk, grizzly bear, furbearers, Arctic grayling, and bull trout are key species. The primary management objective for this area is to encourage natural resource extraction and development (oil and gas, coal, timber). Case study boundaries were defined by RMZ boundaries and the availability of renewable resource data.

This section provides an overview of the detailed Blueberry and Sukunka Case Studies included in Appendices 2 and 3, respectively.

3.1 METHODS

3.1.1 GIS Model

A Geographic Information System (GIS) model was constructed for each study area from readily available government (e.g., TRIM II) digital data. This model included data on elevation, hydrology, forest cover, base features (roads, cutlines, pipelines, railway lines, facilities, clearings, communities), and LRMP management boundaries.

3.1.2 Development and Renewable Resource Trends

In each study area, information on historical human development patterns was generated for two points in time using aerial photographs. In the Blueberry Case Study area, photography from 1950 and 1970 was used; 1969 and 1981 photography was used in the Sukunka study area. General information on development trends in the region was obtained from the OGC and published and unpublished sources (O'Neill 1993; MOF 2002; Salmo unpub. data).

Hunter and trapper harvest data and pertinent inventory and management reports were obtained to document historical trends in harvest and inferred abundance. Representatives of MSRM and WLAP in Fort St. John were also contacted for additional information on renewable resource management and trends.

3.1.2.1 Wildlife Habitat Suitability

While all indigenous species may have some value in assessing environmental conditions and potential effects, evaluating every species in a cumulative effects assessment is impractical. An accepted approach is to select a complementary suite of representative species, groups, or guilds that are useful in quantifying or evaluating the effect of disturbance (Beanlands and Duinker 1983; Noss 1990; Cocklin et al. 1992; Smit and Spaling 1995; Noss et al. 1996).

The four wildlife species selected for the Blueberry and Sukunka Case Studies: moose, caribou, elk, and grizzly bear, are high profile or sensitive species for which reasonable data are available. Representative fish (Arctic grayling and bull trout), furbearer (marten, *Martes americana*), and forest bird species (black-throated green warbler, *Dendroica virens*) were also considered for suitability modelling. However, because there were limited or no historical data available, cumulative effects on these animals were not evaluated quantitatively.

Moose and elk are moderately abundant in both study areas and represent habitat generalists that are relatively tolerant of human disturbance. Woodland caribou and grizzly bear were selected because they are intolerant of human disturbance and generally require large areas of suitable habitat. The 'umbrella species' concept suggests that protection of habitat values and linkages for these large vertebrates will also provide protection for more than 90% of other species found in foothills areas (reviewed in Paquet and Hackman 1995).

Habitat suitability ratings were developed for these species using forest cover data provided by the provincial government. A four class rating system (High, Moderate, Low, Nil) was used. Trends in habitat availability and the amount of habitat in relatively undisturbed core areas were derived for each Case Study area, species, and RMZ. Core areas were defined as habitat greater than 500 m from 'high use features' (roads, trails, pipelines, railway lines, wellsites, communities, and clearings). Additional information on suitability rating development and analyses is provided in Sections 3.1.3 of Appendices 2 and 3.

3.1.2.2 Cumulative Effects Analyses

A number of land use and habitat indicators described in Section 3 were tested to evaluate the relationship between these cumulative effects indicators, development trends, and renewable resource trends. Selected indicators included: road density, cleared/disturbed area, core area, edge area, stream crossing index, riparian roads, and cleared riparian area. Patch size was also considered as part of core area analyses. Stepwise multiple linear regression was used with harvest or harvest success as the dependent variable.

3.1.2.3 Future Scenarios

The A Landscape Cumulative Effects Simulator (ALCES) developed by Forem Technologies Ltd. (www.foremtech.com) was used to visualize the effect of past and future development in the Blueberry Case Study area. Historical development trends were projected over a 100 year period (1950 to 2050) to examine land use patterns, forest age and structure, and wildlife habitat effectiveness.

Indicators used for this simulation were: moose habitat effectiveness; woodland caribou habitat effectiveness; total anthropogenic footprint (ha) and edge (km/km^2); road and trail edge (km/km^2); average forest patch size (ha); average forest age (years); and old growth forest (% of area). Fire regime was run as a constant 125 year cycle for softwood and 100 year cycle for hardwood as recommended by BCF and MELP (1999b). Projections of future land use were based on trends quantified in the Case Study. Three future energy development scenarios were simulated: low growth (1950 to 1998 average development rate); moderate growth (1970 to 1998 average development rate); and high growth (1970 to 1998 development rate plus 20%).

The objective of this simulation was to evaluate the capabilities of the ALCES model to conduct strategic-level simulations of regional landscapes, to provide projections of the natural range of variability, and to compare results provided by ALCES and conventional cumulative effects assessment methods.

3.2 DEVELOPMENT AND RENEWABLE RESOURCE TRENDS

This section summarizes information on past and projected future development and renewable resource trends provided in the Blueberry and Sukunka Case Studies (Appendices 1 and 2).

3.2.1 Development Trends

Active petroleum development in the region commenced in the late 1940's. Oil and gas production has occurred continuously since that time, but cyclical changes in the level of oil and gas exploration and production activity have occurred. Approximately 12,000 wells have been drilled in northeast B.C., with an average of 288 wells each year since 1960. Exploration activity has intensified in the last ten years, with an average of 539 wells per year (Figure 8). Seismic activity records are available only since 1982, but activity over this 20-year period has also continued cyclically, with peak activity in the early 1990's.

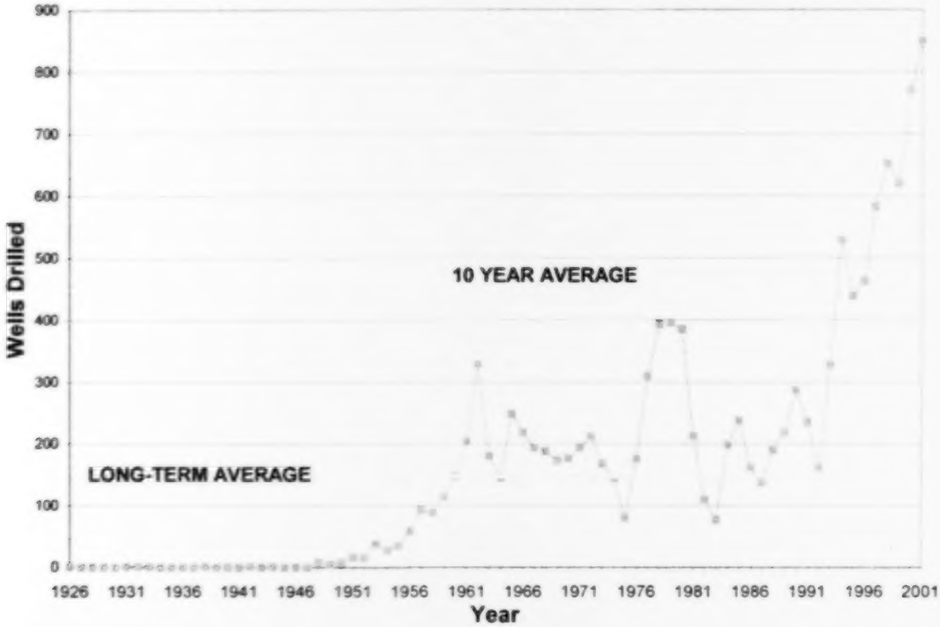
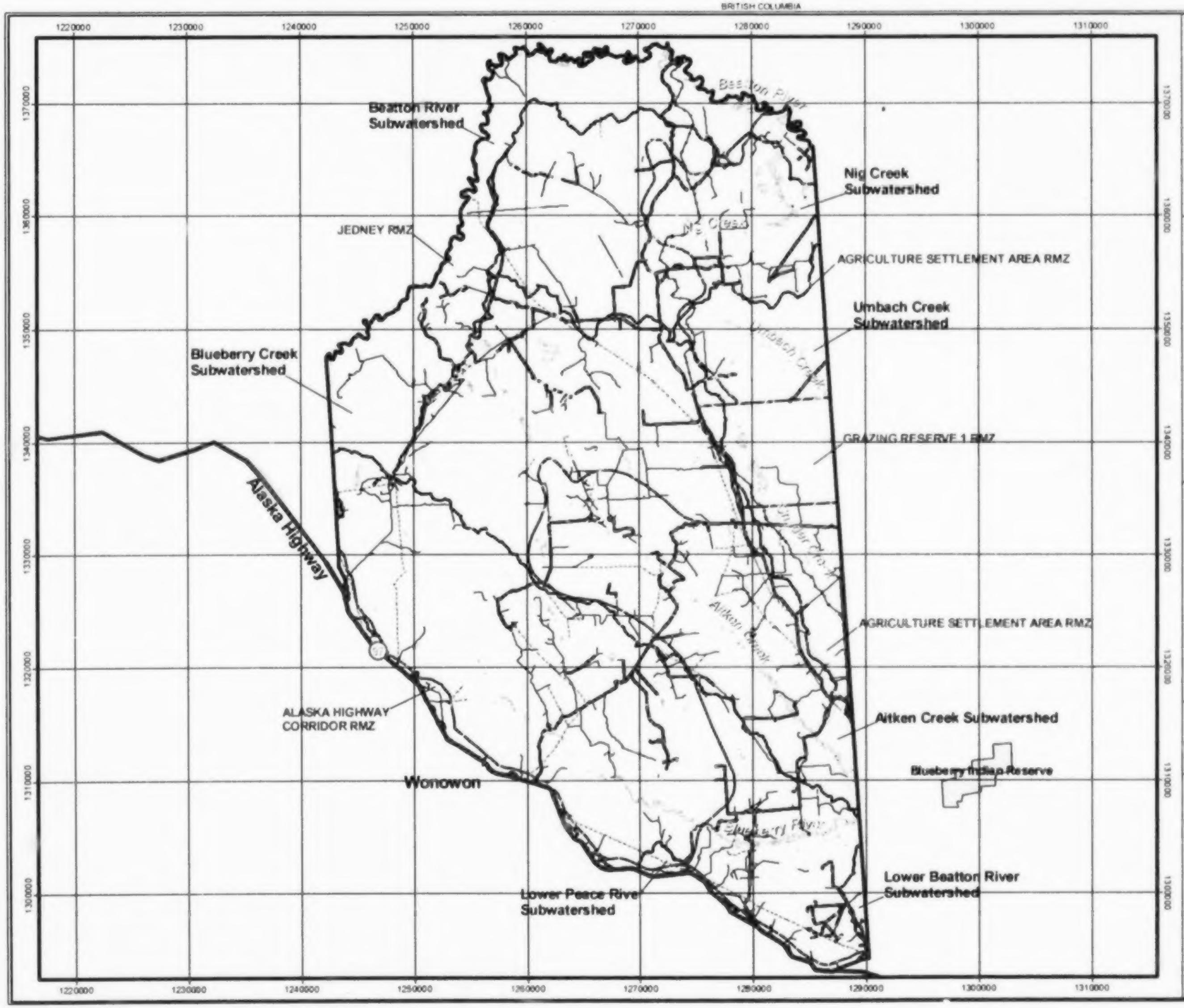


Figure 8. Wells drilled in northeast British Columbia, 1926 – 2001.

Enhanced resource development is the primary land use objective in most of the Blueberry and Sukunka Case Study areas. Existing infrastructure and administrative units in the Blueberry and Sukunka Case Study areas are mapped in Figures 9 and 10, respectively.

Petroleum development began in the early 1950's in the Blueberry area. Since that time, an average of 4 wells, 12 km of secondary roads, 50 km of truck trails, 125 km of cutlines, and 5 km of pipeline have been constructed each year. Annual average construction rates have increased for most features since 1970 to approximately 9 wells, 65 km of truck trails, 135 km of cutlines, and 7 km of pipeline.

In the Sukunka area, petroleum development began in the late 1970's. On average, approximately 1 well and 23 km of secondary roads, 5 km of truck trails, 21 km of cutlines, and 4 km of pipeline have been constructed each year since 1969 in the Sukunka area. Average construction rates for wells increased between 1981 and the present, to approximately 2 wells per year. Development rates for secondary roads and pipelines have remained consistent, while development rates for truck trails and cutlines have declined respectively to 3 km and 15 km per year, presumably due to a slowdown in coal exploration and implementation of low impact seismic techniques.



OGC

Figure 9

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Blueberry Case Study Area

LEGEND

▭	Study Area	/\/	Secondary Road
▭	RMZ Boundary	/\/	Rail Line
▭	Subwatershed	/\/	Pipeline
▭	Indian Reserve	Y	Municipality
/\/	Primary Highway		Hydrography
/\/	Primary Road	/\/	Albers Coordinate Grid

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© 2000 GAIA Consultants Inc.

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0 2 4 8 12 Km

Map Scale 1 : 335 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from the DEM. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data.

Projection:

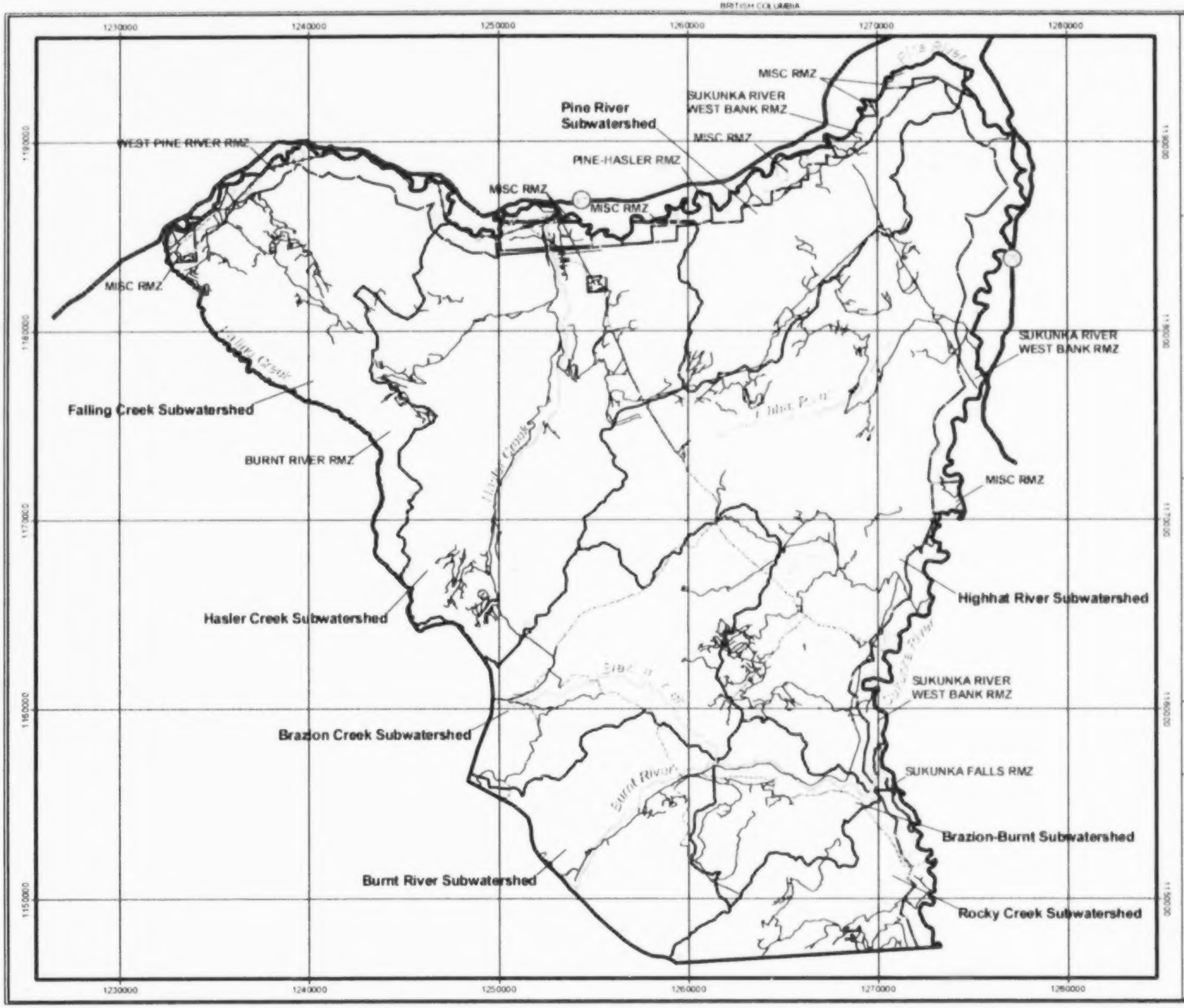
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid



OGC

Figure 10

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Sukunka Case Study Area

LEGEND

▭ Study Area	╱╲╱ Rail Line
▭ RMZ Boundary	╱╲╱ Pipeline
▭ Subwatershed	Hydrography
╱╲╱ Primary Highway	╱╲╱ Albers Coordinate Grid
╱╲╱ Secondary Road	

Map Scale 1:200 000

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from a DEM. Primary Highway taken from ESRI maps and data.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

3.2.1.1 Clearing and Disturbance

Petroleum development, agricultural and residential expansion, and forest harvest are the main development activities that have affected these areas. Petroleum development comprises 20% to 30% of the footprint in both study areas, but clearing for forest harvest and agricultural and residential conversion are also continuing (Figures 11 and 12).

In the Fort St. John area, agriculture has a long history; cattle ranching is the leading farm activity. Large areas of parkland have been converted to grazing and forage production (The ARA Consulting Group et al. 1996). At present, agricultural and residential clearings represent the largest footprint in the Blueberry Case Study area.

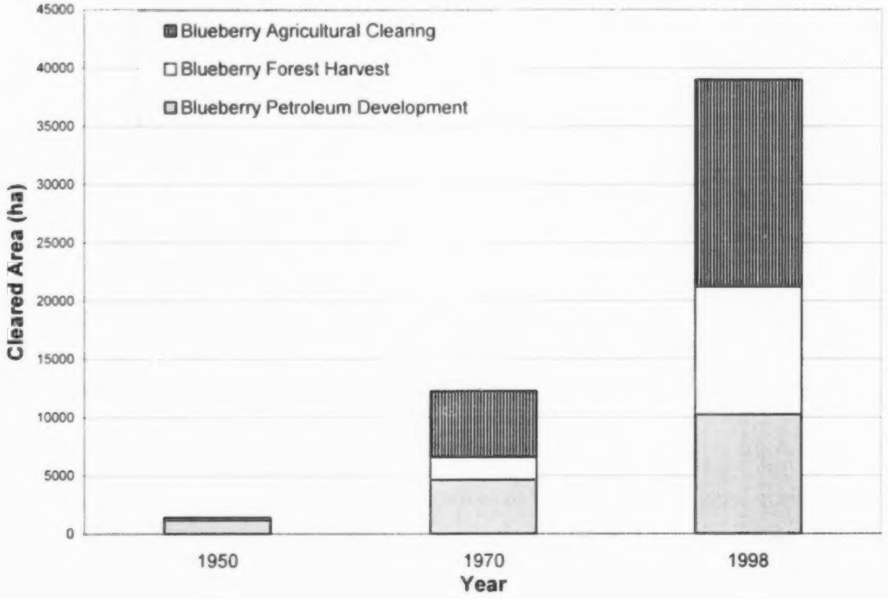


Figure 11. Forest clearing trends in the Blueberry Case Study area.

Forest harvest represents the largest footprint in the Sukunka Case Study area, where agricultural activities are largely restricted to main river valleys.

The Annual Allowable Cut was recently increased in the Fort St. John Forest District and combined coniferous and deciduous harvest is expected to increase in this area (MOF 2002). The Timber Supply Analysis in the Dawson Creek Forest District recommended a constant harvest of coniferous timber, but decreased harvest of deciduous timber (MOF 1996). Forest harvest represents the largest footprint in the Sukunka area, where agricultural activities are largely restricted to main river valleys.

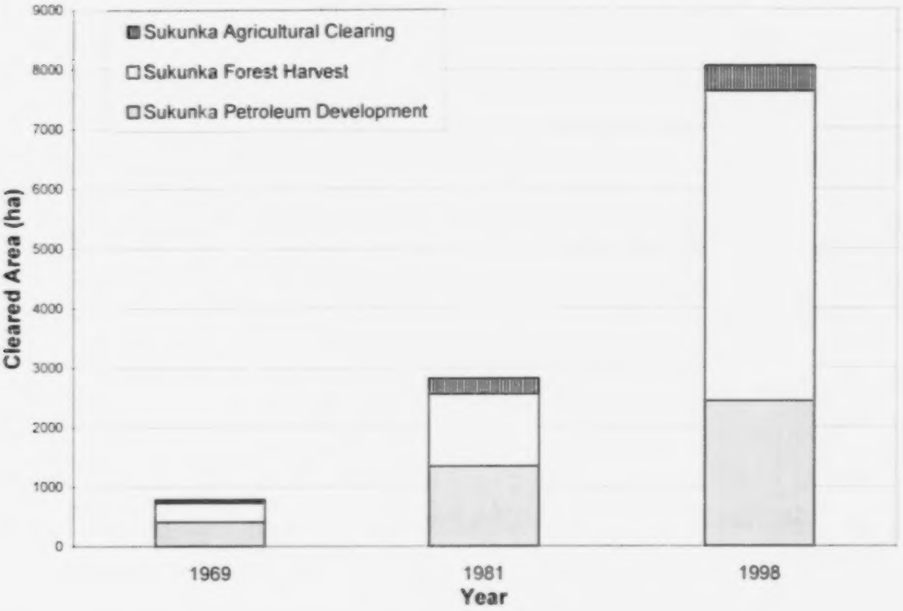


Figure 12. Forest clearing trends in the Sukunka Case Study area.

3.2.1.2 Access Density

The different development history of the Blueberry and Sukunka areas is also reflected in the linear corridor development trends summarized in Figures 13 and 14. Average road and trail density in the Blueberry area increased from 0.19 km/km^2 in 1950 to 1.6 km/km^2 in the late 1990's. The rate at which roads and trails have developed has increased since 1970. Cutlines are the most abundant linear feature in the Blueberry area; this is consistent with other petroleum development and multiple use areas of the Rocky Mountain eastern slopes (Salmo 1999, 2000; Antoniuk 2000). Total corridor density in the Blueberry study area currently exceeds 4 km/km^2 (Figure 13). Development of roads and linear corridors was similar in multiple-use forest and agriculture/settlement RMZs.

In the Sukunka area, average road and trail densities have been consistently lower than in the Blueberry area. They increased from 0.23 km/km^2 in 1969 to 0.8 km/km^2 in the late 1990's. Total corridor density currently exceeds 1.5 km/km^2. Secondary roads were the most common linear feature in both 1969 and the late 1990's (Figure 14). This appears to be related to several factors. First, the topographic relief of the Sukunka study area generally requires longer access roads to upland areas than are required in the rolling Blueberry area. Second, many roads and trails were constructed during a period of intensive coal exploration activity in the 1970's (the rate at which roads and trails have developed has decreased since 1981). Finally, because petroleum development of the Sukunka area occurred later, most geophysical activity in the early 1990's peak used 'low-impact' hand-cut, heli-portable programs, rather than the conventional ground programs used in the Blueberry area. This has reduced the footprint of cutlines in the Sukunka area, and demonstrates the value of project-specific mitigation for management of cumulative effects.

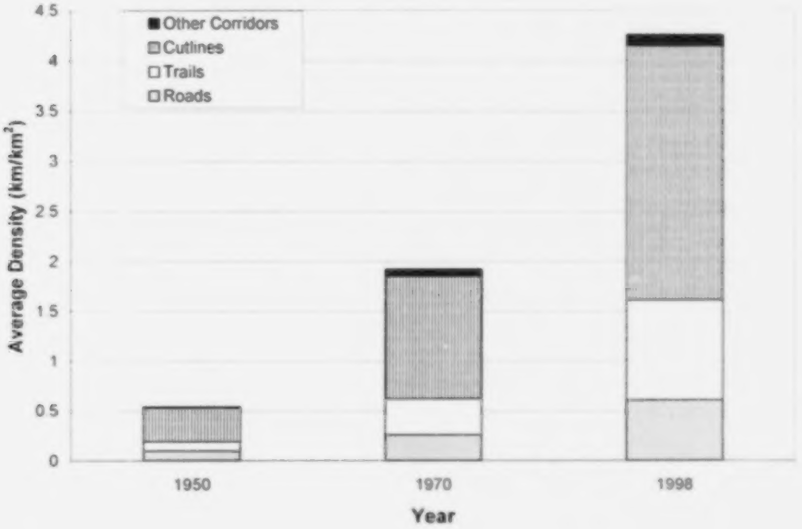


Figure 13. Corridor development trends in the Blueberry Case Study area.

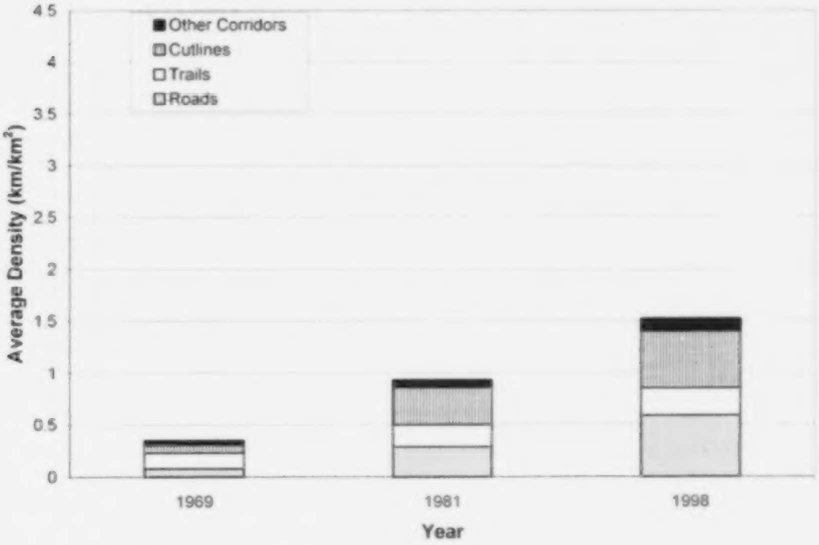


Figure 14. Corridor development trends in the Sukunka Case Study area.

The rate at which access corridors increased was linear in both Case Study areas over the 30 to 50 year analysis period. This demonstrates that the disturbance trajectory can be accurately predicted using the equations derived from the three historical analysis points. In addition, energy infrastructure development trends can be predicted from well drilling trends. The linear nature of these equations also indicates that they can reasonably be used to forecast future disturbance if development practices do not change (e.g., complete shift from conventional to low-impact seismic programs).

3.2.1.3 Core and Edge Areas

Trends in core and edge area availability in the Blueberry and Sukunka Case Study areas are summarized in Figures 15 and 16 respectively. Relatively undisturbed habitat (i.e., >500 m from high use features) has declined in both areas over the last 50 years. Edge area increased over the same period, but at a higher rate than cleared area; this reflects the non-linear nature of 'edge effects' described in Section 2.3.1. In both Case Studies, edge and core availability intersect when both represent approximately 40% of the study area. Theoretical models predict that species such as woodland caribou with low reproductive potential and specialized habitat needs will shift from a random to clumped distribution when their preferred habitat represents less than 80% to 40% of the landscape. For habitat generalists, this shift occurs at 35% to 10% of the landscape (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; Andren 1994; With and Crist 1995; Appendix 1).

In the Blueberry Case Study area, the core area decline rate was roughly linear and averaged 1.2% loss each year over the 50-year study period. Core areas currently comprise 15% of the Blueberry area landscape, less than 20% of that in 1950 (Figure 15). Loss of core area was similar in multiple use forest and agriculture/settlement RMZs.

The core area decline rate in the Sukunka Case Study area was curvilinear, and initially occurred at a much higher rate than was observed in the Blueberry area. The loss of core areas slowed considerably after 1981 due to the decline in road construction (Figure 16).

3.2.1.4 Patch Size

The size of core areas in both Case Study areas has changed from few very large contiguous patches to many fragments. As shown in Figures 17 and 18, the average size of remaining core areas decreased between each study interval and currently consists of a large number of very small fragments that provide limited security for large or intolerant species. The Blueberry Case Study area is much more fragmented than the Sukunka Case Study area, consistent with previously described development trends. ALCES simulations indicate that average forest patch size in the Blueberry Case Study area has decreased by 25% over the past 50 years (12 to 8 ha).

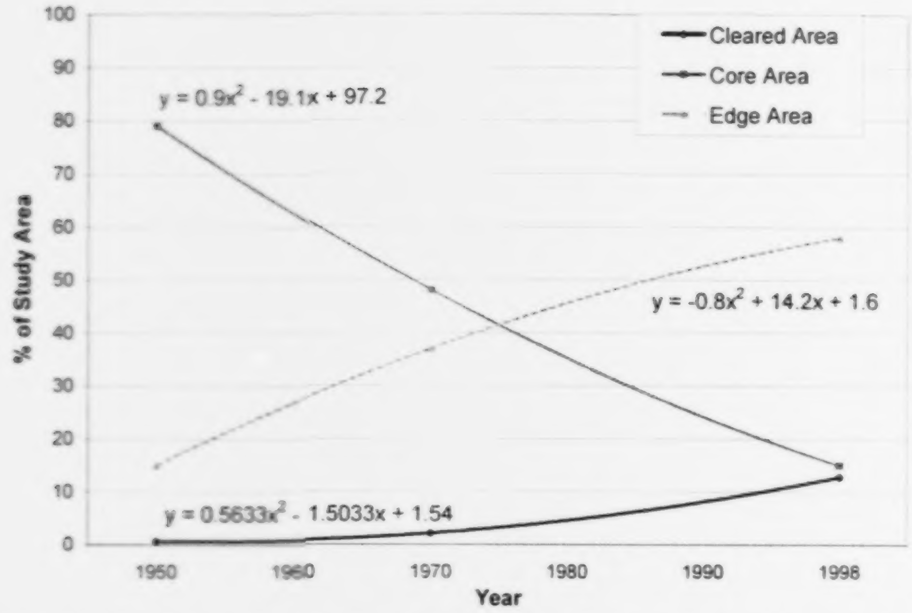


Figure 15. Trends in core, edge, and clearing in the Blueberry Case Study area.

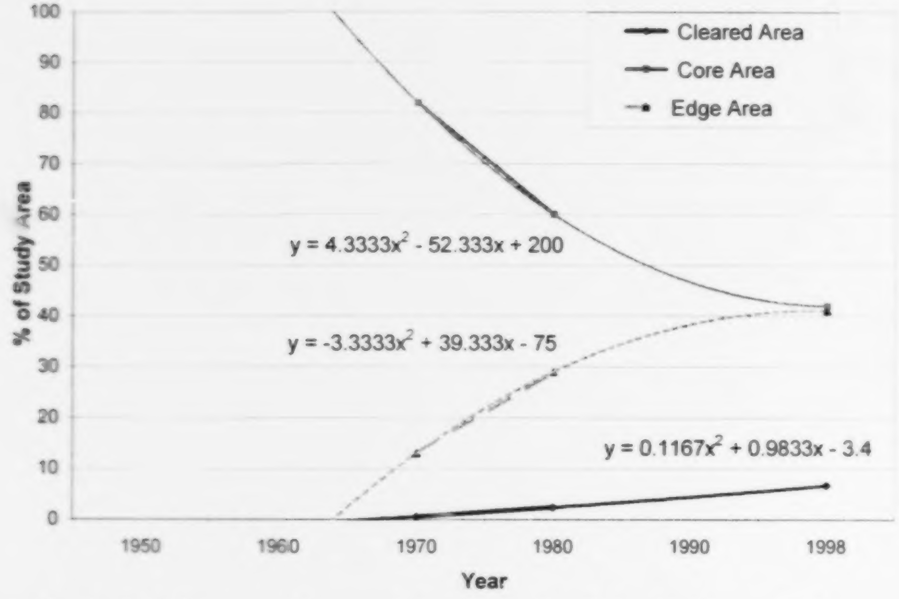


Figure 16. Trends in core, edge, and clearing in the Sukunka Case Study area.

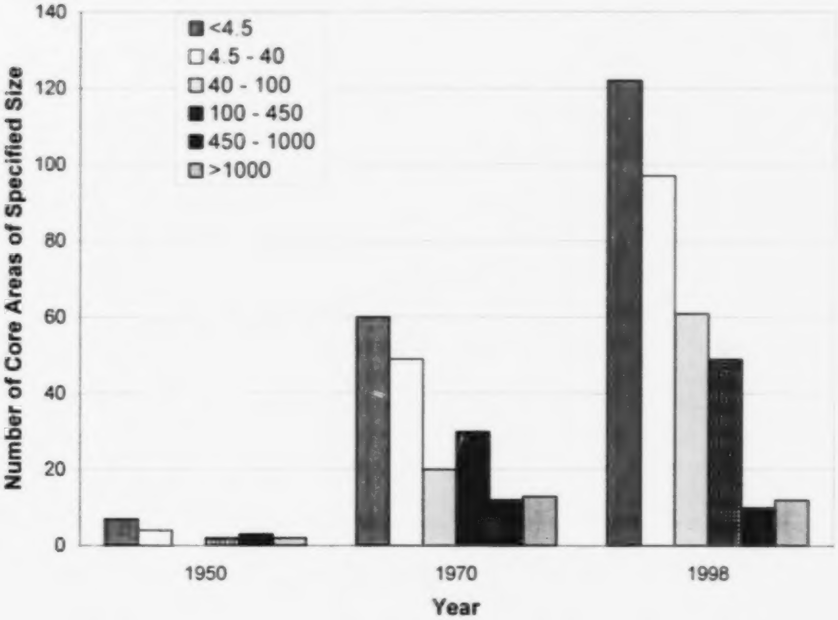


Figure 17. Core area size distribution in the Blueberry Case Study area.

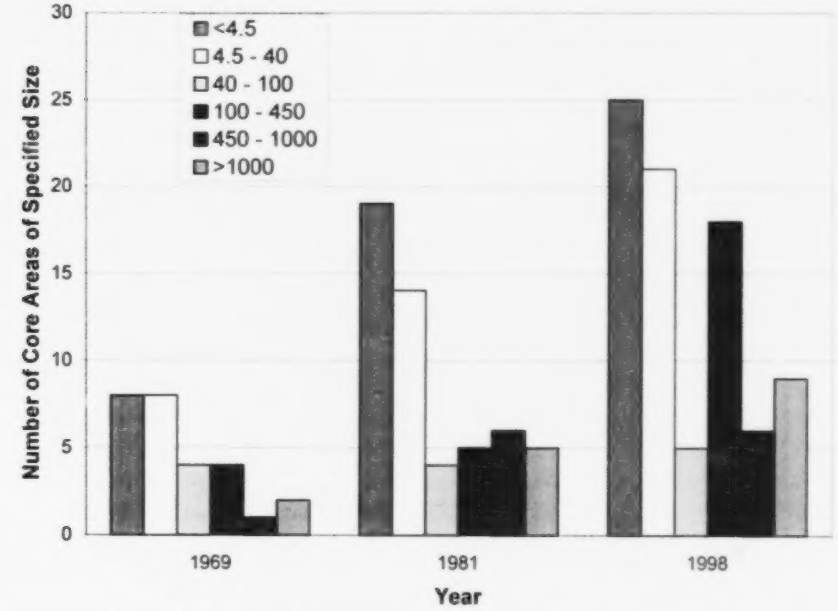


Figure 18. Core area size distribution in the Sukunka Case Study area.

3.3 RENEWABLE RESOURCE TRENDS

A summary of moose and woodland caribou trends in the Blueberry and Sukunka Case Study areas is presented here. These two representative species provide a contrast between two ungulates with moderate and low ecological resilience. Moose are a habitat generalist with moderate reproductive potential and are relatively tolerant of human disturbance. Woodland caribou are a habitat specialist with low reproductive potential and are comparatively intolerant of human disturbance. Additional information on elk, grizzly bear, and other species is included in the Case Study reports in Appendices 2 and 3.

Key factors limiting moose and woodland caribou populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk),
- natural abiotic and biotic factors (predation, disease, snow depth, fire),
- decline in habitat effectiveness, and
- habitat loss and alteration (clearing, fire suppression).

Naturally caused changes in fish and wildlife populations occur as a result of natural disturbances such as fire, disease, parasites, pests, floods, droughts, predation, and severe weather conditions. Winter snow depth is a critical factor affecting wildlife populations in northeast British Columbia; historical snow depth records for the Fort St. John airport are presented in Figure 19. Limiting snow depths are assumed to be 40 cm for deer, 50 cm for elk, and 65 cm for moose (Nietfeld et al. 1985). The 7-year period of mild winters beginning in 1984 provided very good conditions for ungulate population growth.

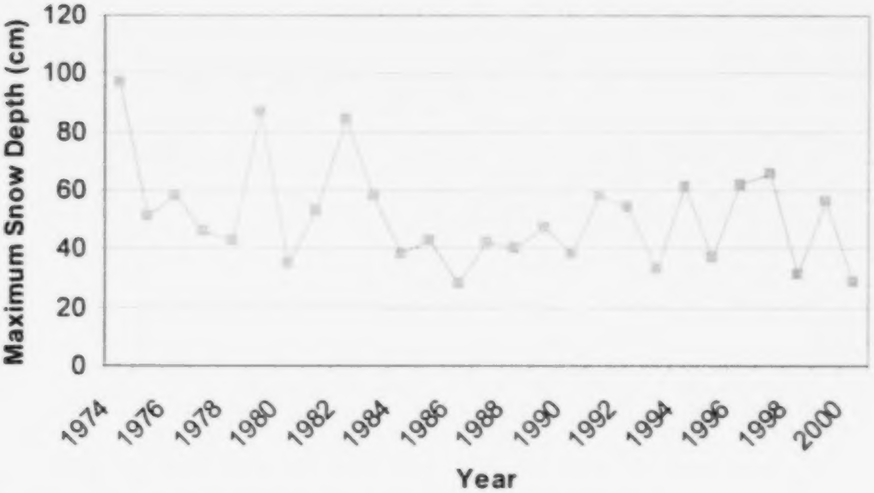


Figure 19. Maximum snow depth at Fort St. John airport.

3.3.1 Moose

Moose are highly sought after by recreational and subsistence hunters. They are the most abundant large mammal in the Blueberry Case Study area and approximately 65% of the area is rated as Moderate to High suitability habitat (Table 7, Figure 20). Moose are common but less abundant in the Sukunka area, with only one-third of the Case Study area rated as Moderate to High suitability habitat (Appendix 3).

Moose are common but less abundant in the Sukunka area, and only one-third of the area is rated as Moderate to High suitability habitat (Appendix 3).

Table 7. Current moose habitat suitability in the Blueberry Case Study area.

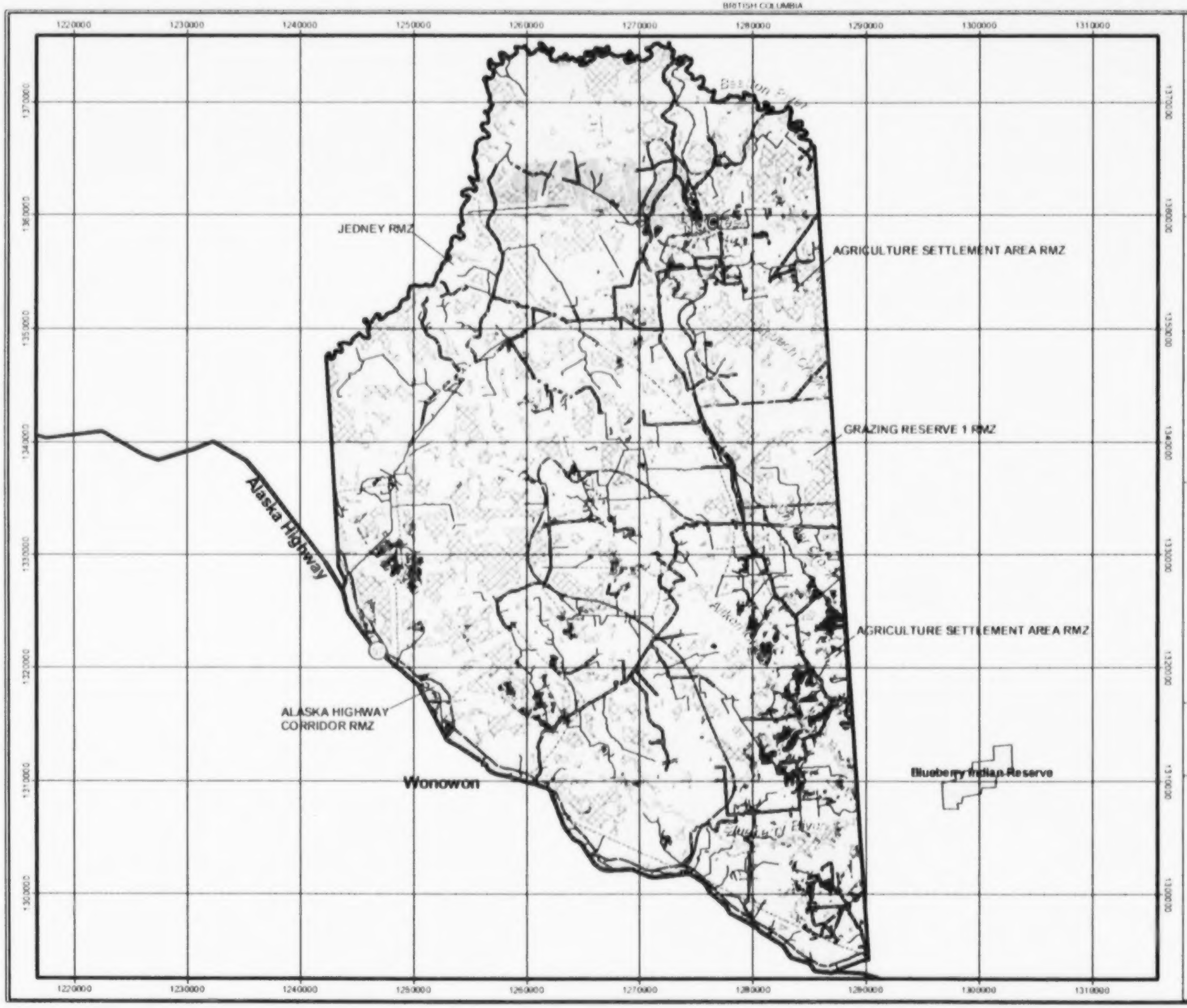
Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Blueberry Overall	13,165	5	158,933	60	82,680	31	8,260	3
Agriculture Settlement RMZ	9,022	10	59,564	64	21,720	23	2,818	3
Alaska Highway RMZ	317	7	3,057	65	757	16	542	12
Grazing Reserve RMZ	8	<1	6,108	67	2,581	28	375	4
Jedney Enhanced Resource RMZ	3819	2	90,204	58	57,623	37	4,525	3

ALCES simulations predict that moose habitat effectiveness has gradually declined in the Blueberry Case Study area over the last 50 years as average forest age has increased.

OGC

Figure 20

Current Moose Habitat Suitability in the Blueberry Case Study Area



LEGEND

- Study Area
- RMZ Boundary
- Core Area
- Indian Reserve
- Primary Highway
- Primary Road
- Secondary Road
- Rail Line
- Pipeline
- Y Municipality
- Hydrography
- Albers Coordinate Grid

Moose Habitat Suitability Rating

- ☐ Nil
- Low
- Moderate
- ■ High
- No Data

Map Scale 1 : 335 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of moose habitat in the Blueberry Case Study area (Figure 21). Each Monte Carlo simulation (shown in individual colour) was run over a 100 year period beginning in 1950. The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is typical of productive boreal forest. These simulations demonstrate that moose habitat in this area has a large natural range of variability due to fire.

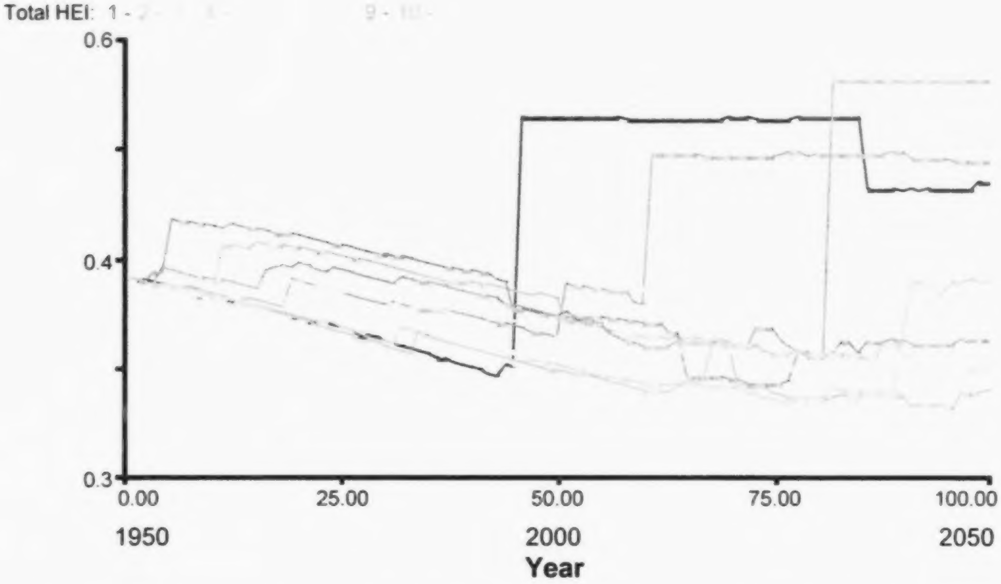


Figure 21. Predicted range of natural variability for moose habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

Limited population data are available for the two study areas, and trends in moose numbers must be inferred from isolated surveys and harvest statistics in Management Unit (MU) 7-45 (Blueberry) and 7-22 (Sukunka). In MU 7-45, population estimates derived from surveys in 1982 and 1998 were identical (2,200 animals with average density of 0.35/km^2), but the population was concluded to stable to decreasing in the early 1980's (Harper 1988), and stable or increasing more recently (MELP 1998). This suggests that although cyclical changes in abundance have occurred, the moose population in the Blueberry area has remained comparatively stable over the last twenty years. Harper (1988) reported that this is likely about half the population of the mid-1960's, and approximately one quarter of predicted habitat capability (Harper 1988). Predation and human mortality appear to be regulating the moose population in the Blueberry area.

Harper (1988) estimated that annual human-caused moose mortality was 17% of the population in MU 7-45 and 10% of the population in MU 7-22. Natural mortality was estimated to contribute an additional 5% in both areas. Recreational hunter kill and related crippling loss was identified as the largest source of mortality in both areas, and ranged from 6% to 11% of the MU 7-22 and 7-45 populations, respectively.

Moose harvest statistics from MUs 7-45 and 7-22 were used as a population index to evaluate changes in relative abundance. Analysis of historical moose harvest patterns in this region is confounded by changes in harvest regulation, and by increasing use of off-road vehicles that has improved access to previously remote areas. Nonetheless, although hunter effort has declined over the last 25 years, the average number of days required for a hunter to kill a moose has increased in MU 7-45 (Figure 22), and yearly harvest has declined. Moose harvest and hunter success in the Sukunka Case Study area remained relatively constant over the same period (Appendix 3).

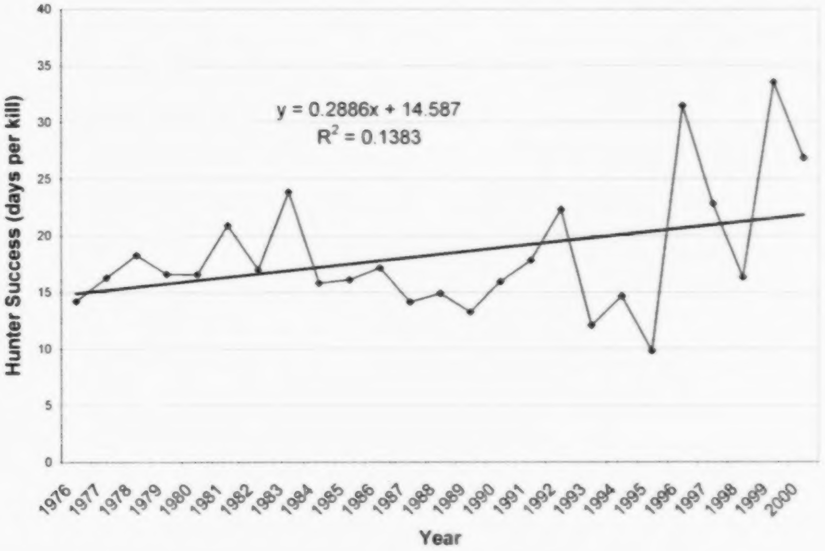


Figure 22. Historical moose hunter success in Management Unit 7-45 (Blueberry Case Study area).

Moose population estimates derived from surveys in the Blueberry area in 1982 and 1998 suggest that the population has been stable over the long-term. In contrast, moose harvest and harvest success in this area is slowly declining. Although changes in harvest could be interpreted as evidence of a population decline, it more likely represents harvest-related reductions in abundance of legal animals near disturbance features (Rempel et al. 1997; Schneider and Wasel 2000). Under these circumstances, the presence of relatively undisturbed (i.e., core) areas may be important for population persistence.

Core areas with High and Moderate Suitability moose habitat have declined in both the Blueberry and Sukunka areas over the last fifty years and currently comprise only 10% to 12% of available habitat (Figure 23). This indicates that most moose now reside in edge areas where disturbance and direct human mortality risk is increased and habitat effectiveness may be reduced. However, these local effects may be offset by reduced wolf and bear predation, greater availability of early seral stages, and restricted legal harvest such that population declines are not observed at the regional or management unit scale (Schneider and Wasel 2000).

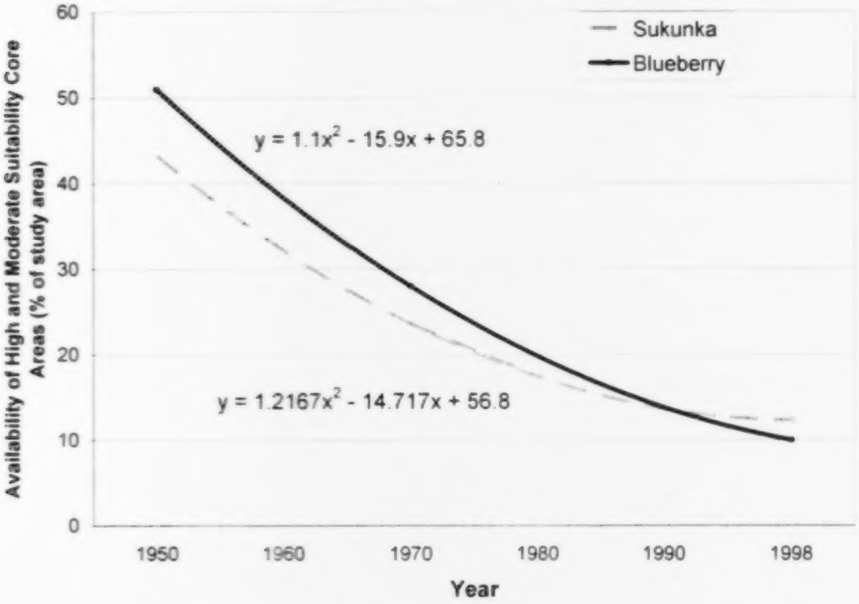


Figure 23. Trends in availability of Moderate and High suitability core habitat for moose.

In both areas, the portion of High and Moderate Suitability habitat within core areas remained relatively constant over the past 30 to 50 years. This indicates that development was randomly distributed throughout the Blueberry and Sukunka Case Study areas. It also suggests that generalized landscape analyses using indicators such as core area can be substituted for more detailed evaluations of moose habitat quality and availability at the regional scale.

ALCES simulations predict that moose habitat effectiveness in the Blueberry Case Study area will gradually decline in future as a result of ongoing forest harvest, access construction, agricultural conversion, and natural succession. Both the historical and projected future decline in moose habitat effectiveness in the Blueberry Case Study area are within the range of natural variability (Appendix 2).

Moose harvest and hunter success (days per kill) were compared to a variety of land use and habitat indicators to evaluate the effect of combined man-made disturbance on relative abundance. In the Blueberry area, yearly moose harvest success was inversely related to the level of disturbance (Figure 24) and directly related to the availability of core areas (Figure 25). This means that the highest yearly harvests tended to occur at earlier stages of fragmentation when more core area was available and disturbance (road, trail, and cutline density and cleared area) was lower.

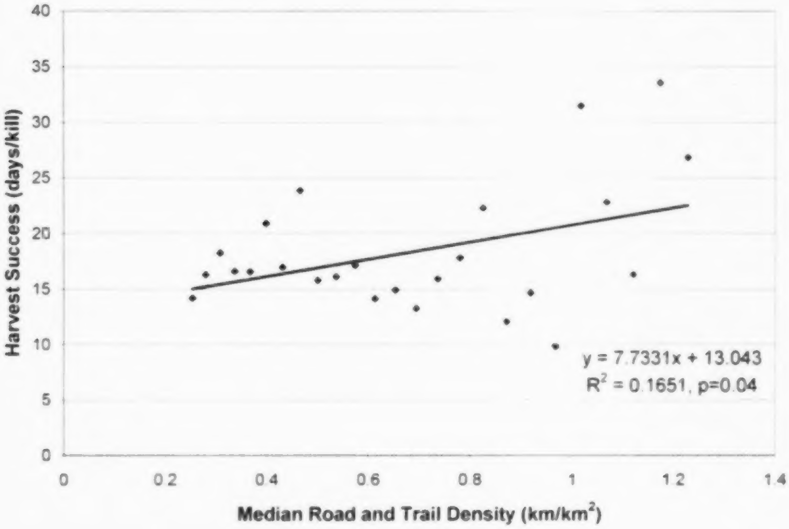


Figure 24. Relationship between moose harvest success and roads in the Blueberry Case Study area.

In the Blueberry area, median road and trail density provided a statistically significant prediction of harvest success ($R^2 = 0.17$; $p<0.05$); regression equations based on all other linear corridor densities were nearly significant ($R^2 = 0.13$ to 0.15; $p<0.09$). Land use indicators (total corridor density, road density, and trail density) individually provided better predictions than habitat indicators (cleared area, core area, edge area, good core area). Core area, a generalized habitat indicator, provided slightly better predictive ability than an indicator incorporating habitat suitability (i.e., moderate and high suitability core area). Multiple linear regression equations incorporating complementary disturbance and habitat indicators (e.g., median roads plus trails and core area; cleared area and core area) were able to explain more of the variability in annual harvest success ($R^2 = 0.28$; $p<0.04$; Appendix 2).

There was no consistent relationship between land use or habitat indicators and moose harvest in the Sukunka study area (Appendix 3).

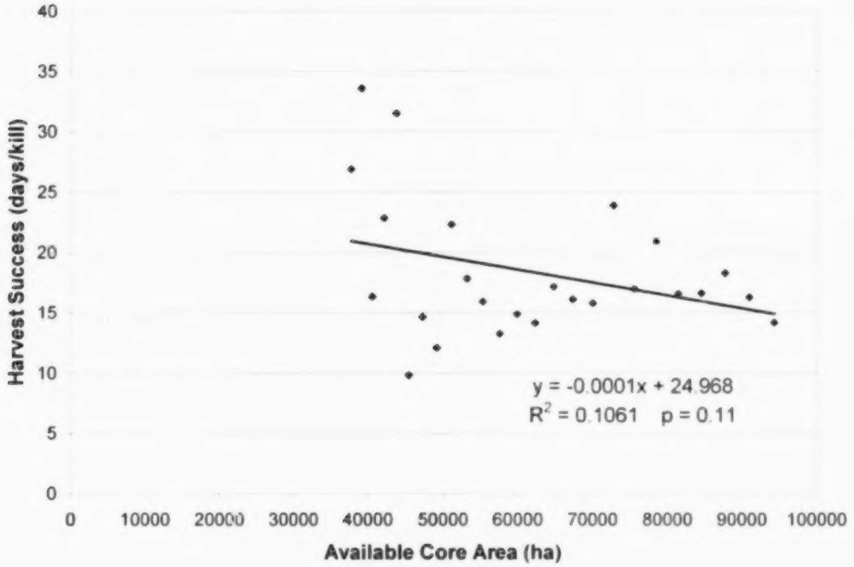


Figure 25. Relationship between moose harvest success and core area in the Blueberry Case Study area.

3.3.2 Woodland Caribou

Woodland caribou occur at low densities in the Sukunka Case Study area. Just over 10% of the area, mainly isolated patches of alpine tundra and subalpine forest is rated as Moderate to High suitability habitat for this species (Figure 26, Table 8). In the Blueberry Case Study area, where woodland caribou have historically been documented at low densities, Moderate to High suitability caribou habitat is limited to mature and old seral lodgepole pine (*Pinus contorta*) forest and black spruce lowlands present on approximately 6% of the area (Appendix 2).

Woodland caribou population data from these two areas is extremely limited, and trends must be inferred from regional surveys and MU 7-22 (Sukunka) harvest statistics. Harper (1988) concluded that a population crash of approximately 75% occurred in this region in the early 1970's, possibly due to a series of deep snow winters in the late 1960's combined with predation. Concurrent declines in woodland caribou populations were also observed in other populations in southern British Columbia and western Alberta (Edmonds and Bloomfield 1984; Stelfox and Stelfox 1993; Harding and McCullum 1994; Dzus 2001). Harper (1988) identified population-limiting factors as predation and loss of critical wintering habitat.

Table 8. Current woodland caribou habitat suitability in the Sukunka Case Study area.

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Sukunka Overall	940	<1	14,511	12	88,255	73	17,811	15
Burnt River RMZ	940	<1	14,259	13	80,943	74	13,886	13
Misc RMZ	0	0	42	1	1,965	64	1,065	35
Pine-Hasler RMZ	0	0	0	0	469	79	126	
Sukunka Falls and West Bank RMZs	0	0	78	1	3,354	59	2,261	40
West Pine R. RMZ	0	0	132	6	1,524	72	474	22

Annual direct caribou mortality in the Sukunka and Blueberry areas is very low. Sport harvest has not been allowed in the Blueberry Case Study area for at least 20 years. In the Sukunka area, harvest is restricted to trophy bulls, and reported harvest since 1976 averages one animal every 3 years (Appendix 3). While vehicle mortality of woodland caribou is an issue in some areas (e.g., along the Alaska Highway in the vicinity of the Prophet River), it is very low in the Sukunka area (Antoniuk 1994). There was no relationship between land use or habitat indicators and woodland caribou harvest in the Sukunka study area (Appendix 3).

Relatively undisturbed core areas with High and Moderate suitability woodland caribou habitat have declined in both the Blueberry and Sukunka areas over the last fifty years and currently comprise less than 6% of available habitat (Figure 27). In the Sukunka Case Study area, available core area (Figure 16) is below the 50% caribou persistence threshold (Table 2, Appendix 1), and High and Moderate suitability core area is well below this threshold. This suggests that the probability of woodland caribou persistence in the Sukunka Case Study area is reduced.

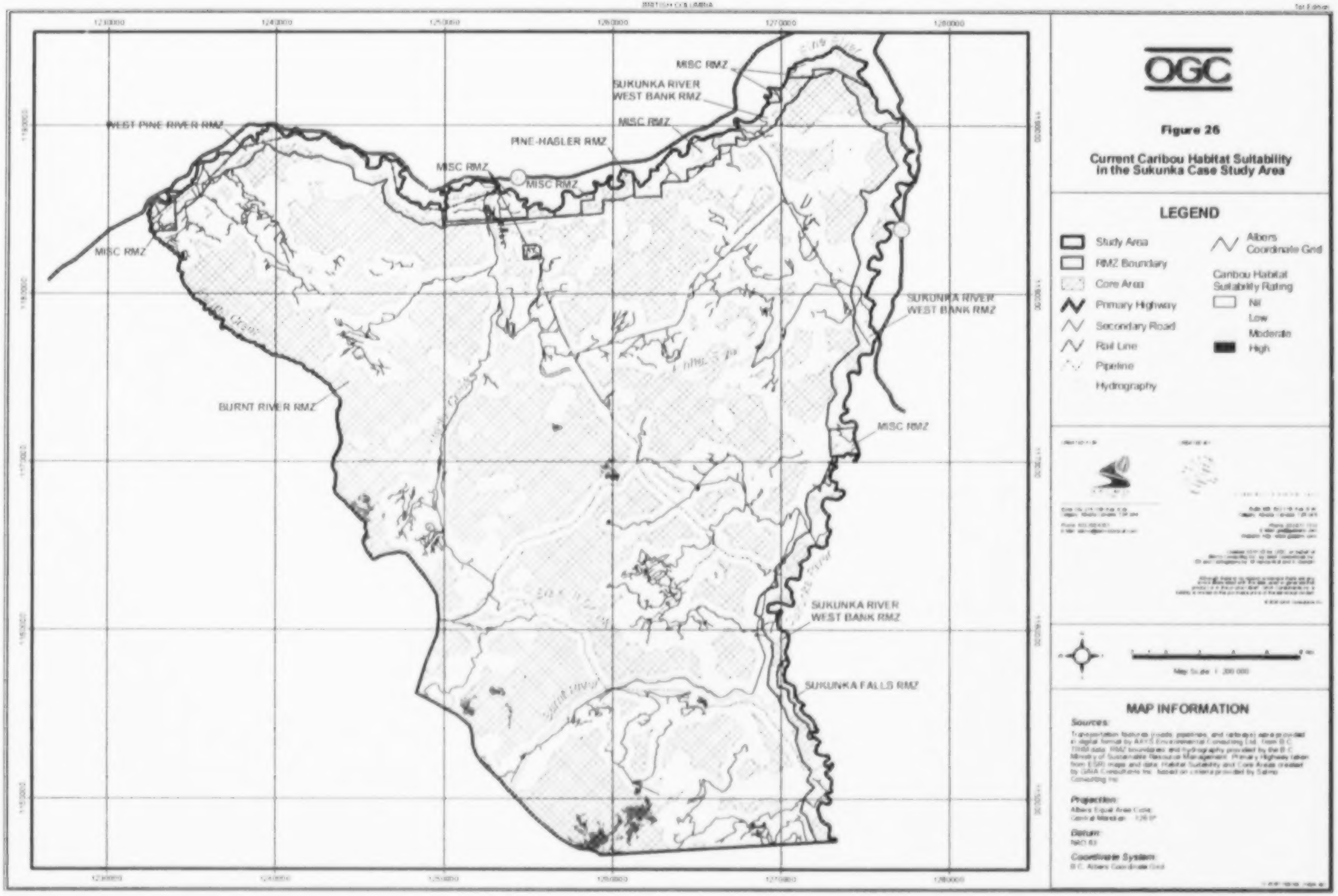


Figure 26

Current Caribou Habitat Suitability in the Sukunka Case Study Area

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:

Albers Equal Area Conic

Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

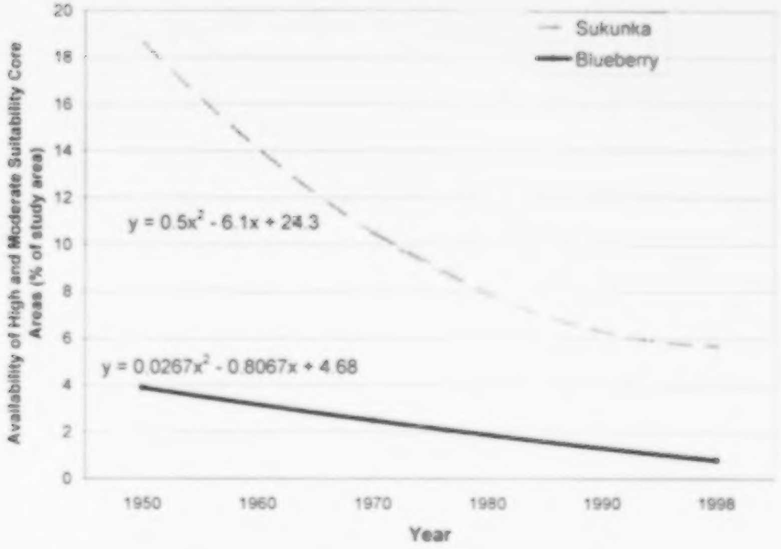


Figure 27. Trends in availability of Moderate and High suitability core habitat for caribou.

Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of woodland caribou habitat in the Blueberry Case Study area (Figure 28). Each Monte Carlo simulation was run over a 100 year period beginning in 1950.

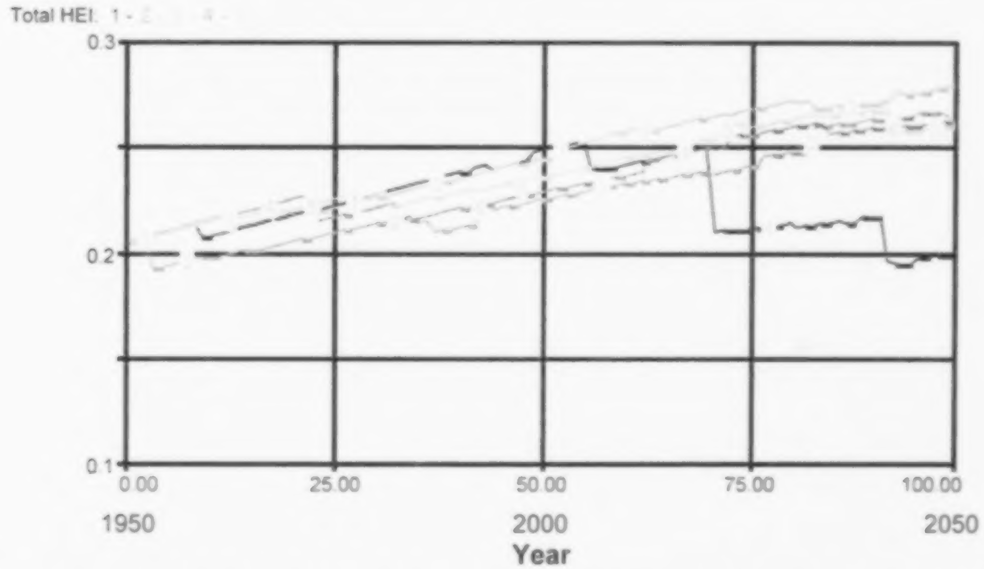


Figure 28. Predicted range of natural variability for caribou habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is somewhat low relative to occupied caribou range in the boreal forest. These simulations demonstrate that in the absence of human disturbance, woodland caribou habitat in this area is gradually improving as forest age increases and that natural variability due to fire is low in this area.

At present, total access corridor density in the Blueberry Case Study area exceeds the 3 km/km^2 woodland caribou persistence threshold (Table 4, Appendix 1). Available core area (Figure 15) is well below the 50% caribou persistence threshold (Table 2, Appendix 1), as is High and Moderate suitability core area (Figure 27).

An ALCES simulation was also conducted to evaluate the effects of human development on caribou habitat effectiveness in the Blueberry Case Study area. The simulation was begun in 1950 and uses development trends calculated for this area; habitat effectiveness was assumed to be lost near disturbance features due to edge effects (see Section 2.3.1 and Appendix 1). These simulations indicate that the Blueberry area provided no effective habitat for woodland caribou by 1980 (Figure 29) due to indirect effects of clearing, land conversion, and access corridor construction. This loss is well below the range of natural variability (Figure 28).

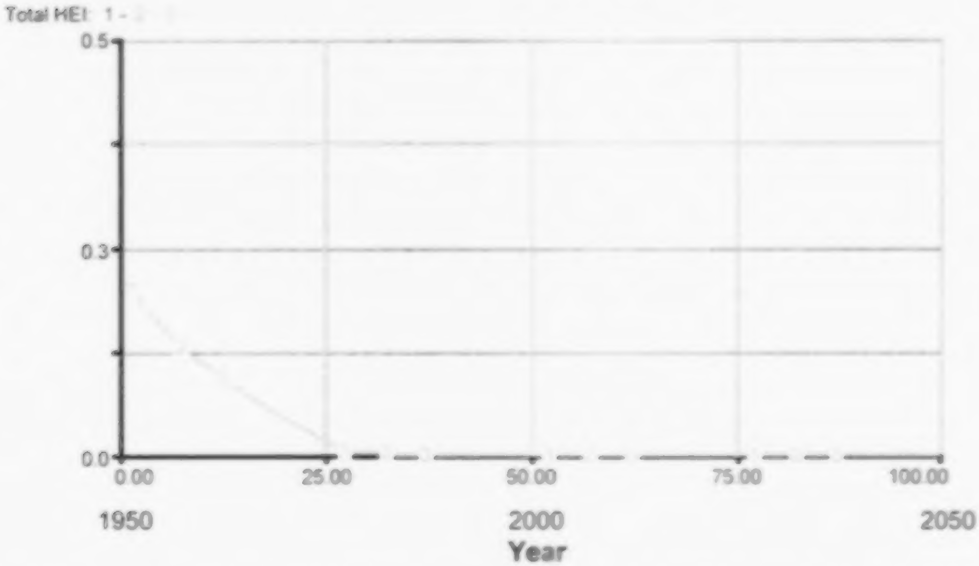


Figure 29. Predicted caribou habitat effectiveness in the Blueberry Case Study area with human development (Habitat Effectiveness Index on y axis).

Cumulative effects evaluations using several independent land use and habitat-based methods consistently conclude that woodland caribou are unlikely to persist in the Blueberry Case Study area. This is consistent with observations that this area received only occasional woodland caribou use by the early 1980's (Harper 1988).

3.4 APPLICABILITY OF LAND USE AND HABITAT INDICATORS

This section evaluates the suitability of the land use and habitat indicators considered most appropriate for cumulative effects assessment and management in northeast British Columbia.

3.4.1 Access Density

Access density is considered to be a useful land use indicator because it integrates the many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance (Forman and Hersperger 1996). Case Study results confirm that access density can be used to document cumulative effects in northeast British Columbia.

Road density, trail density, and total corridor density provided statistically significant ($p<0.05$) predictions of moose harvest in the Blueberry Case Study area (Appendix 2). This finding is consistent with studies from elsewhere that demonstrate increased mortality risk near roads and trails (Appendix 1).

Average road and trail density was also found to be a good predictor of remaining core area in both Case Studies. The combined graph provided in Figure 30 demonstrates that availability of relatively undisturbed core areas decreases exponentially as road and trail density increases. In the Blueberry and Sukunka areas, 60%, 40%, 30%, and 10% core area thresholds summarized in Table 2 correspond to average road and trail densities of 0.4 km/km^2, 0.72 km/km^2, 0.97 km/km^2, and 1.82 km/km^2, respectively.

Although road and trail density appears to be a practical cumulative effects indicator, the Case Studies also demonstrate that documented relationships between road density and large wildlife species may not be directly applicable to northeast British Columbia. Animal response to habitat and disturbance features such as roads can be considered at two scales of analysis. At the regional scale, individuals or groups select home ranges or territories that meet all their life history need (2nd order selection). Within this home range or territory, individuals and groups select or avoid areas based on site-specific features (3rd order selection; Rettie and Messier 2000; Apps et al. 2001; Szkorupa 2002). For example, wolf packs appear to select areas with low road densities and low densities of humans in populated landscapes. In many remote areas however, wolves appear to select areas close to roads, trails, and seismic lines. This suggests that it is not the physical feature the road represents that wolves avoid, but the positive correlation between road density and number of encounters with humans (reviewed in Whittington 2002). Prey species, including moose, caribou, and elk, appear to respond to disturbance in the opposite manner (Dyer 1999; Schneider and Wasel 2000), presumably to reduce the risk of wolf predation.

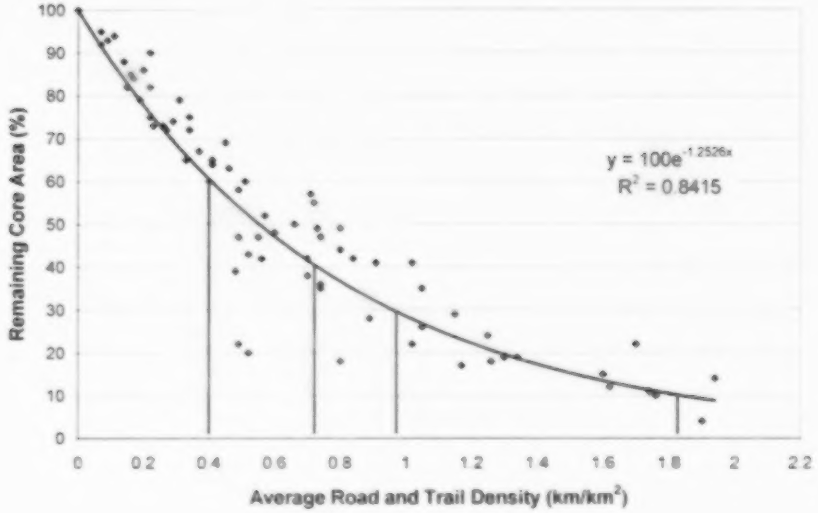


Figure 30. Relationship between road and trail density and remaining core area.

Northeast British Columbia has relatively low road and population densities when compared with most locations where road density effects have been studied. O'Neill (1993) estimated that 20% of cutlines in the region were passable by four-wheel drive vehicles, but concluded that actual use of these linear features was low. This is similar to findings in areas of the Alberta foothills with similar population density (Kansas and Collister 1999; Salmo unpub. data).

In addition, as noted in Appendix 1 (Section 2.3.4), physiological and behavioural responses of individuals may not be translated into reductions in animal numbers, particularly for species with high reproductive rates, species able to habituate to repeated disturbance (e.g., elk), or populations adjacent to protected or wilderness areas. For example, established models (Section 2.3.3, Appendix 1) predict that elk habitat effectiveness in the Blueberry and Sukunka study areas has been reduced by more than 35% due to construction of roads and trails (Figures 7 and 30). Realized reductions in habitat effectiveness have not affected local populations, however, as the expansion of the road and trail network has coincided with a dramatic increase in elk populations in these areas. O'Neill (1993) also concluded that loss in habitat effectiveness is not a significant issue for many species in this region.

Another issue relates to the way in which road or access density indicators are calculated. Most documented road density relationships and thresholds are based on average (mean) values. The average value is a measure of central tendency and is most applicable to samples with a symmetrical or normal (e.g., bell curve) distribution. When samples are asymmetrical or skewed however, calculated average road density is greatly influenced by extremely high values. In these cases, the median (middle measurement) is the preferred method to describe central tendency (Zar 1984).

Figures 31 and 32 present access density values calculated for 1 km^2 'cells' in the Blueberry and Sukunka Case Study areas. Because road and trail curves are skewed to the left, calculated average road and trail densities are much larger than calculated median densities. This discrepancy is greatest at earlier stages of fragmentation, as observed in the Sukunka area. In addition, moving window analyses are particularly sensitive to boundary effects (Ake 1995), which can further bias average values. As linear features and associated fragmentation increase, the frequency distribution becomes more symmetrical. For example, when all corridors in the Blueberry area were combined, the current average (5.9 km/km^2) and median (5.2 km/km^2) were closer (Figure 31).

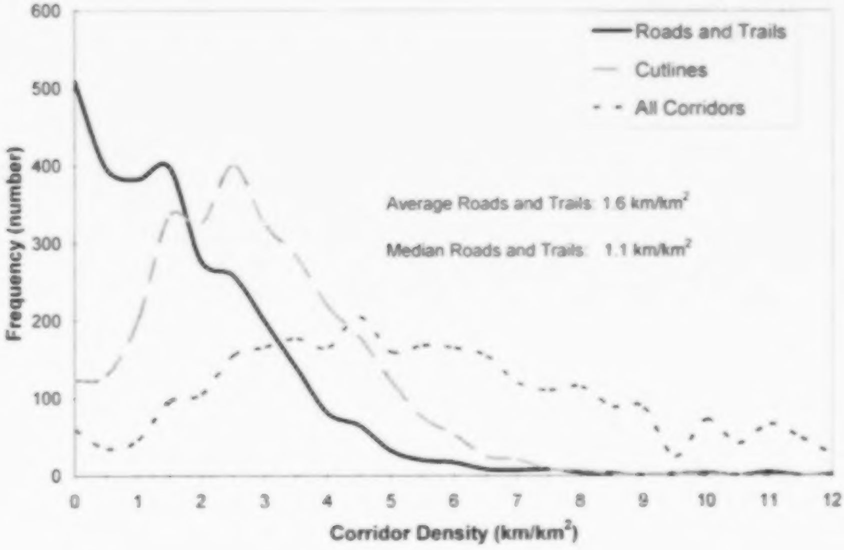


Figure 31. Current linear feature frequency in the Blueberry Case Study area.

In the current study, median road and trail density was the indicator that best predicted moose and elk harvest, and was a better predictor than average density. Although average access density is the normal reporting convention, use of median access density is considered to be more appropriate in forested areas of northeast British Columbia.

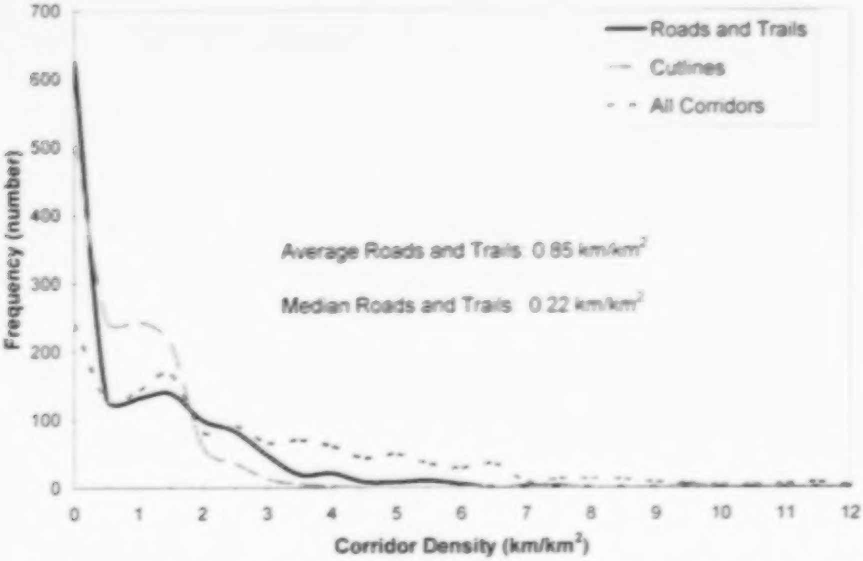


Figure 32. Current linear feature frequency in the Sukunka Case Study area.

3.4.2 Stream Crossing Index

Stream crossing indices were calculated for all subwatersheds in the Blueberry and Sukunka Case Study areas using TRIM II hydrography. Watershed cumulative effects risk was rated as High in both the Blueberry and Sukunka Case Study areas; this suggests that further field investigation is warranted to document actual risk (BCF and BCE 1995b).

TRIM II hydrography data are believed to dramatically overestimate the actual length of stream present in the field, so comparative analysis was undertaken in the Blueberry Case Study area using readily available 1:50,000 scale digital hydrography data. The TRIM II data identified more than 3 times as many streams as the smaller scale (1:50,000) data in each subwatershed. Watershed riparian indicators calculated with 1:50,000 hydrography data were significantly ($P<0.01$) higher than those calculated with TRIM II data – this elevated the riparian cumulative effects hazard in the Case Study area from Low to High. Stream crossing indices calculated with smaller scale data were significantly ($P<0.02$) lower than those calculated with TRIM II data – this reduced the watershed cumulative effects hazard from High to Medium.

Smaller scale (1:50,000) hydrography data are considered to be most appropriate for calculation of watershed cumulative effects indicators because they more accurately identify potential fish-bearing watercourses.

3.4.3 Core Area

Remaining core area is considered to be one of the most practical cumulative effects indicators. This habitat index provides a useful complement to access density by identifying the availability and location of areas where minimal human impacts have occurred. In fragmented landscapes, these areas have increased importance for population persistence; application of a minimum core area indicator can help minimize further fragmentation.

Loss of core area occurred at a much higher rate than did clearing, reflecting the non-linear nature of edge effects. The core area decline rate differed between the two study areas as a result of different development patterns. In both Case Study areas however, observed trends were consistent with theoretical fragmentation models that have identified critical changes at around 40% to 60% core area for habitat specialists such as woodland caribou and interior forest songbirds.

There is a generally accepted cumulative effects method that was developed to calculate core security areas for grizzly bear (e.g., Gibeau et al. 1996, Appendix 1). This method requires information on seasonal habitat suitability, disturbance features, and assumed or actual human use of these features on a seasonal basis. This method has recently begun to be applied to a variety of other large mammals, including moose. In the Blueberry and Sukunka Case Studies, generalized core area availability was found to have equal predictive power for moose and elk population indices as a more detailed (and costly) indicator that integrated habitat suitability. This indicates that core area can be used as a generalized landscape indicator for tolerant habitat generalists such as moose and elk. More detailed, species-specific evaluations will be required for intolerant or sensitive species, such as woodland caribou, that rely on relatively large and isolated patches of suitable habitat for persistence.

3.4.4 Patch and Corridor Size

Insufficient data on species abundance and distribution were available to test effects of patch and corridor size. In both case study areas, core areas changed from a few very large contiguous patches to a many fragments over the 30 to 50 year analysis period. Smaller fragments provide limited security for large or intolerant species, so patch and corridor size should be integrated into core area analyses to quantify those areas with value for focus species.

3.4.5 Utility of Existing Data

The Case Studies also evaluated the utility of readily available data for use in cumulative effects models and assessments. For reasons summarized below, the availability and quality of existing data affected study conclusions.

The readily available TRIM II digital data provided to be insufficient to accurately identify disturbance features. Most significantly, many clearings are not identified, so it is impossible to distinguish industrial, commercial, and recreational facilities from forest cutblocks, houses, and agricultural fields. In addition, information on the age of the feature, reclamation status, and intensity of use is not available; this is critical for differentiating between high-use and low- or no-use features.

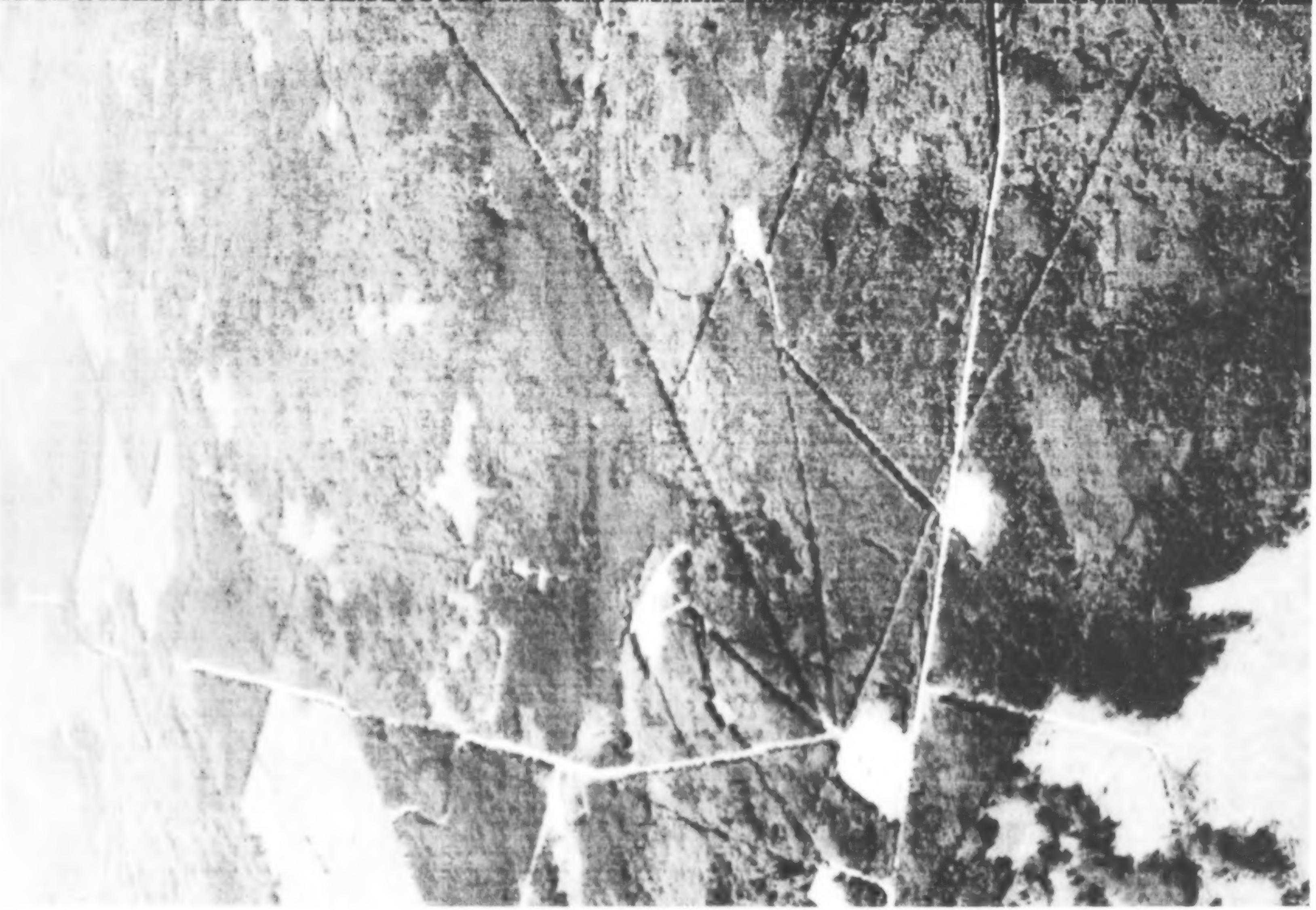
Existing forest cover data available from the British Columbia Provincial Government are known to be inaccurate and do not include insufficient information to develop reliable habitat suitability ratings. The Provincial Government is currently developing wildlife habitat maps based on the 1:250,000 Broad Terrestrial Ecosystem Classification scheme (BEI; RIC 1998) that are designed to be more suitable for cumulative effects analyses. In addition, medium to large scale Terrestrial Ecosystem Mapping (TEM; RIC 1999) is available for some areas. Use of these maps would enhance the consistency and accuracy of habitat suitability ratings and also reduce the cost to the applicant.

Analyses of watershed indicators are sensitive to the scale of the hydrography layer used. The readily available TRIM II digital data includes numerous computer-generated watercourses that do not occur in the field. This causes critical stream-length based indicators (riparian area cleared, stream crossing index) to be inaccurate. For this reason, watershed indicators should be calculated using the 1:50,000 watershed polygons and stream network provided in the British Columbia Watershed Atlas. This information data is considered to be most appropriate for this indicator because it more accurately identifies potential fish-bearing watercourses.

Finally, the evaluation of relationships between development and renewable resource trends was primarily hindered by the lack of data on species abundance and distribution. In particular, the original plan to include a Case Study in a muskeg-dominated area important for woodland caribou could not be achieved due to a lack of information on the boreal ecotype in this region.

SECTION 4: THRESHOLDS IN NORTHEAST BRITISH COLUMBIA

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



4. THRESHOLDS IN NORTHEAST BRITISH COLUMBIA

Cumulative effects management is largely focused on defining how and where human activities can be continued without irreversible net harm to habitat, fish and wildlife populations, or biodiversity. Most cumulative effects ultimately result from the combined effects of small routine projects or activities. Nevertheless, the potential cumulative effects of these everyday activities are rarely considered in a formal way. This is at least partly due to the perception that complex, expensive, and time-consuming technical methods such as species-specific habitat modelling are required. Available literature and practice in other jurisdictions demonstrates that cumulative effects indicators can be used to quickly and economically assess the risk of adverse cumulative effects.

A suite of four complementary land use and habitat indicators was identified as the most appropriate for assessing and managing cumulative effects on fish and wildlife habitat and populations in northeast British Columbia. These indicators quantify the area affected directly and indirectly by access corridors and the number and size of relatively undisturbed areas. They are:

Land Use Indicators

1. Access density (km of linear corridors per unit area).
2. Stream crossing index (number of crossings per km of stream).

Habitat Indicators

1. Core area (% of analysis area).
2. Patch and corridor size (area in ha or width in m).

This section discusses recommended cumulative effects indicators, presents candidate thresholds for each indicator, outlines a process to use these thresholds for cumulative effects assessment and management, and identifies implementation and data needs.

4.1 CUMULATIVE EFFECTS THRESHOLDS

Indicators present information about the likelihood of adverse cumulative effects, but do not directly measure the acceptability of these effects. Thresholds are objective, science-based standards used to define the point at which the indicator changes from an acceptable to unacceptable condition.

Established chemical thresholds are available to help proponents and regulators identify the point or range at which cumulative effects on air and water quality changes from an acceptable to an unacceptable condition. This allows development activities to proceed without detailed review until a defined threshold is reached. Once the threshold range is reached however, additional review or regulation is implemented.

The British Columbia Approved Water Quality Guidelines (MELP 2001) are an example of science-based thresholds. Water quality problems are considered non-existent if the substance concentration is below the guideline value. In cases where the substance concentration exceeds its guideline, an enhanced evaluation of water quality is desirable. In some instances, local 'Water Quality Objectives' may be developed to protect the most sensitive water use at a specific location, accounting for local circumstances (MELP 2001).

There is inevitably some uncertainty with science-based thresholds, and economic, social, and technical considerations are normally incorporated when thresholds are established. Regulators may build in a safety margin by establishing a threshold below the point of irreversible effects or below the lowest point at which a behavioural, physiological, or population-level effect has been detected. In other cases, regulators may adopt a less stringent threshold that provides a lower, but still adequate level of protection at less cost to the proponent or society. Regardless, the rationale for threshold derivation should be clear and the process used to derive the threshold should be transparent.

Ecological thresholds have not been as widely applied as chemical thresholds, but thresholds based on meaningful land use, habitat, or population indicators can also be used to evaluate the acceptability of project-specific and cumulative effects. All the indicators identified in the literature review provided in Appendix 1 have some value for resource management. Resource managers in other jurisdictions have concluded that the most practical thresholds are land use and habitat indicators that quantify the effect of human development. Candidate thresholds for northeast British Columbia are provided in Section 4.4.2.

4.2 CASE STUDY FINDINGS

The applicability of recommended land use and habitat indicators was tested in the Blueberry and Sukunka Case Studies provided in Appendices 2 and 3. The presence of apparent thresholds was also investigated. Conclusions based on these indicators were also compared to those obtained with a more detailed method that examined predicted habitat quality for moose, woodland caribou, elk, and grizzly bear.

4.2.1 Development Trends

In both Case Studies, the area directly affected by linear features and clearings has increased at a consistent and predictable rate over the last thirty to fifty years. The rate of core habitat decline was much more rapid than the rate of forest clearing; core area loss was highest during the first fifteen to twenty years of development. These trends were consistent in both study areas, even though the rate of core area decline differed between the two areas due to their differing development patterns.

Development appeared to be randomly distributed across the study areas and the amount of high and moderate suitability habitat remained relatively constant for all species over the evaluation period. Road and trail density was the best predictor of remaining core area. Observed trends were consistent with theoretical fragmentation models that have identified critical thresholds of 40% to 60% core area for habitat specialists (e.g., woodland caribou, interior forest birds). Fragmentation has decreased forest patch size and there are now a large number of very small fragments that provide limited security for large or intolerant species. The abundance of old growth forest has declined in prevalence in 'productive' forest stands and increased in 'non-productive' forest stands.

4.2.2 Renewable Resource Trends

A direct comparison between development and renewable resource trends was limited by the lack of quantitative data on historical fish and wildlife populations. Wildlife harvest statistics from the last twenty-five years were used as a population index to indirectly evaluate the relationship between human activity, habitat availability, and wildlife populations. Median road and trail density provided statistically significant ($p<0.05$) predictions of moose and elk harvest trends over the last twenty-five years. Habitat indicators incorporating suitability ratings performed no better than generalized indicators.

Moose and elk populations have not been measurably affected by ongoing petroleum development, forest harvest, and agricultural conversion. Current moose habitat effectiveness in the Blueberry area is predicted to be within the range of natural variability, and the moose population has remained relatively stable over the last twenty years. However, localized reductions in moose density and changes in sex and age ratios have likely occurred as a result of legal harvest. Elk populations in the Blueberry and Sukunka Case Study areas have increased dramatically, coincident with expansion of the road and trail network. These results demonstrate that land use thresholds developed in more populated areas may overstate cumulative effects risk in northeast British Columbia.

Although the Blueberry Case Study area historically supported woodland caribou, this area received only occasional caribou use by the early 1980's (Harper 1988). Simulations conducted with ALCES indicate that caribou habitat effectiveness has been dramatically reduced by clearing and access development; this decline is well below the range of natural variability (Figures 28, 29). Other land use and habitat-based evaluations also concluded that woodland caribou are unlikely to persist in the Blueberry Case Study area. Woodland caribou in the Sukunka Case Study area appear to be at increased risk from combined activities.

Habitat loss, fragmentation, direct and indirect mortality, and disturbance have also increased the risk of cumulative effects for both sensitive and tolerant species. Implementation of better methods to assess and manage cumulative effects is warranted.

4.3 TIERED THRESHOLDS

Tiered ecological and land use thresholds are recommended for northeast British Columbia. Tiered air and water quality thresholds are already used in British Columbia, and ecological thresholds be derived and implemented as part of a clear and integrated framework. With this approach, science- based and politically defined Cautionary, Target, and Critical thresholds are defined to reflect increasing degrees of concern. These thresholds are then integrated with defined management actions so that operating rules are clear for all parties. Figure 33 illustrates the tiered threshold model defined by the Clean Air Strategic Alliance (CASA) for management of potential acidification input (AENV and CASA 1999). This model identifies three receptor-based management tiers: Critical, Target, and Cautionary Thresholds.

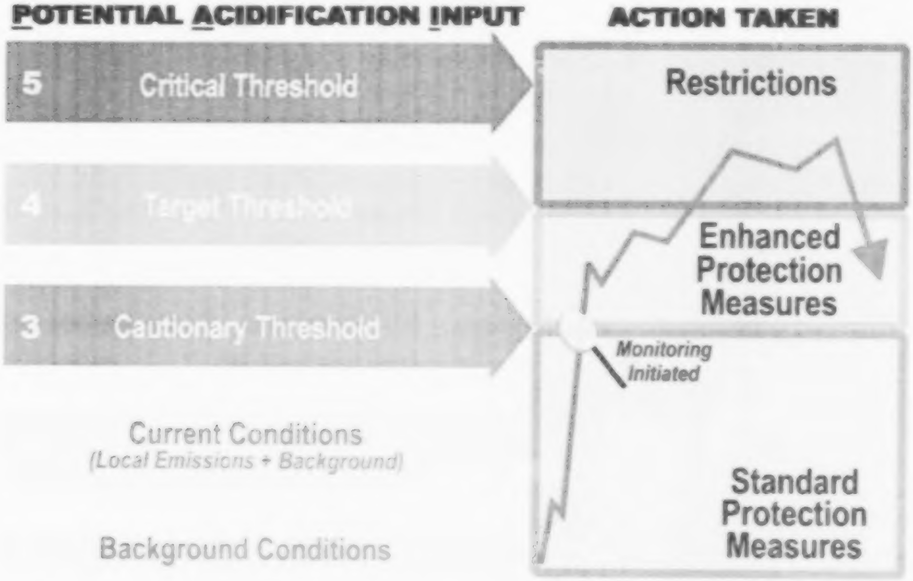


Figure 33. Development of tiered cumulative effects thresholds.

In this graphic, the red line in the Action Taken box represents the status of the cumulative effects indicator (here, potential acidification input).

Critical Thresholds reflecting minimum habitat parameters (or maximum land use) can be established using the lowest observed effects level (Bull 1991, 1992), the range of natural variability, the probability and severity of an undesirable effect (Francis and Shotton 1997), or population parameters such as predicted risk of population extinction or persistence (Lande 1987; Lamberson et al. 1992). As shown in Figure 33, management action is designed to keep the cumulative effects indicator below this threshold.

Target Thresholds reflect the desired value or range of habitat parameters. As shown in Figure 33, the desired condition was identified as 40 to 70% habitat availability, with the Target Threshold set at 40%. The Target Threshold represents the point at which 'Restrictive Protection Measures' would be initiated.

No Net Habitat Loss is an example of a Target Threshold that is routinely applied to protect fisheries habitat. Although unavoidable habitat loss may be legally authorized at the regulator's discretion, it requires implementation of Restrictive Protection Measures, namely negotiation of a formal agreement to compensate for lost habitat.

Cautionary Thresholds reflect the point at which monitoring or 'Enhanced Protection Measures' would be implemented to slow the rate of change and determine actual ecological response. As shown in Figure 33, cooperative or project-specific monitoring is initiated once the Cautionary Threshold is exceeded. Monitoring helps ensure that sufficient local data exist to confirm scientific predictions of target and critical thresholds, along with the benefits of prescribed management actions.

Where there is not enough information to define a threshold value or range, a decision can be made to define an interim threshold between the Cautionary and Target Thresholds. The sustainable threshold would be established only after further monitoring, research, and stakeholder consultation (AENV and CASA 1999).

4.4 IMPLEMENTING TIERED THRESHOLDS

This Case Studies report provides a suite of cumulative effects indicators and candidate thresholds. Experience in other jurisdictions clearly demonstrates that although this science-based review is an important initial step in threshold development, all affected groups and individuals must have the opportunity to participate in threshold implementation. This is because implementation is a shared responsibility that will be most effective where thresholds are acknowledged to be reasonable and based on accepted science and traditional observation (see also Volume 1, Section 4.6.2).

The following process will likely be required to implement ecological thresholds in northeast British Columbia:

1. Develop explicit definitions of acceptable change,
2. Adopt candidate thresholds as a foundation for further discussion,
3. Evaluate the ecological and economic implications of threshold implementation,
4. Develop standardized analysis, reporting, and review methods,
5. Provide required land use data in a consistent and readily available format,
6. Implement a pilot study to validate thresholds and optimize analysis, reporting and review methods, and
7. Continue monitoring to refine thresholds and management actions.

Further discussion of this threshold implementation process is provided below. The specifics provided here are intended to reflect the resource management and review regime in the region. The actual process will need to be developed with participant input.

4.4.1 Defining Acceptable Change

In northeast British Columbia, the three established LRMPs provide direction on acceptable change as defined by a wide array of groups. The thresholds presented here have been directly linked to designated 'Provincial Land Use Categories' in Table 9.

Table 9. Level of protection based on Provincial Land Use Categories.

Protected Areas and Special Management Areas:

These lands are managed to protect specific ecological values. They are considered primary source habitat for all species; they provide relatively undisturbed areas for wilderness and backcountry recreation. Thresholds should be established below the lowest detected effect level for Identified Wildlife or the most sensitive species to provide a **100% level of protection** (a Very Low Risk as defined by MELP 2000).

General Management Areas and Identified Landscape Management Units:

These multiple use lands are managed for a wide variety of resource values. They are secondary source habitat for most species; they provide a mixture of undisturbed and modified areas. Thresholds should be established below the lowest observed effect level for most species to provide a **90% level of protection** (a Low Risk as defined by MELP 2000). More protective thresholds may be established in defined Landscape Management Units.

Enhanced Resource Development and Agriculture/Settlement Areas

These multiple use lands are managed for intensive resource development in full compliance with best management practices. They are neutral or sink habitat for most species and consist primarily of human-modified areas. Thresholds should be established to provide an **80% level of protection** (a Moderate Risk as defined by MELP 2000). More protective thresholds may be established in defined Landscape Management Units.

Quantitative protection levels have been included here to help visualize acceptable change. A 90% level of protection infers that 10% of species or ecosystems in a defined area may be subject to adverse effects.

Natural range of variability can also be used to establish acceptable change, as reflected in the Landscape Unit Planning Guide (BCE and MELP 1999b). Case Study results suggest that the ALCES model is one option to help define natural range of variability for a range of indicators.

4.4.2 Candidate Thresholds

Figures 34 and 35 respectively present graphical summaries of road density and core area guidelines and thresholds identified in the literature review (Appendix 1). These guidelines and thresholds, as well as the Case Studies (Appendices 2 and 3), were used to generate candidate tiered road density and core area thresholds for northeast British Columbia (Table 10).

The candidate thresholds provided in Table 10 were derived to reflect conditions in northeast British Columbia, the levels of protection inferred from Provincial Land Use Categories, and the following environmental management principles established by MELP (2000) for regulation of activities affecting the environment:

Sustainability:	Resources should not be used beyond their capacity to be naturally replenished, both in quality and quantity, for the well-being of future generations.
Precautionary Principle:	The onus of proof should be on parties undertaking actions that could cause serious or irreversible environmental damage to provide beyond a reasonable doubt such that no damage will be caused.

4.4.2.1 Landscape Road and Trail Density

Access density is a land use indicator that integrates many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance. Case Study results confirm that this indicator can help document the risk of cumulative effects in northeast British Columbia. Three candidate access density thresholds have been identified: landscape road and trail density, watershed road and trail density, and total corridor density. Road and trail density would be used for generalized landscape and watershed analyses while total corridor density would be used for analysis in designated woodland caribou habitat.

Road and trail density thresholds have been detected or proposed to protect both terrestrial and aquatic systems (Figure 31). Established standards may not be directly comparable because there have been considerable differences in the type of linear features included in road density calculations. Candidate road and trail density thresholds for northeast British Columbia are provided in Table 10.

Combined road and trail densities must be calculated in a standardized manner to ensure that project proposals are evaluated consistently and equitably. The recommended approach here is to include those features most likely to receive high use in this region. This would include primary roads, secondary roads, truck trails passable by four-wheel drive vehicle, and designated off-highway or all-terrain vehicle (OHV/ATV) trails. Other linear features such as utility corridors (pipelines, powerlines, and railway rights-of-way) and cutlines are less likely to receive high use. When calculated on this basis, road and trail density was found to be a good predictor of moose and elk harvest success and remaining core area in the Blueberry and Sukunka Case Studies.

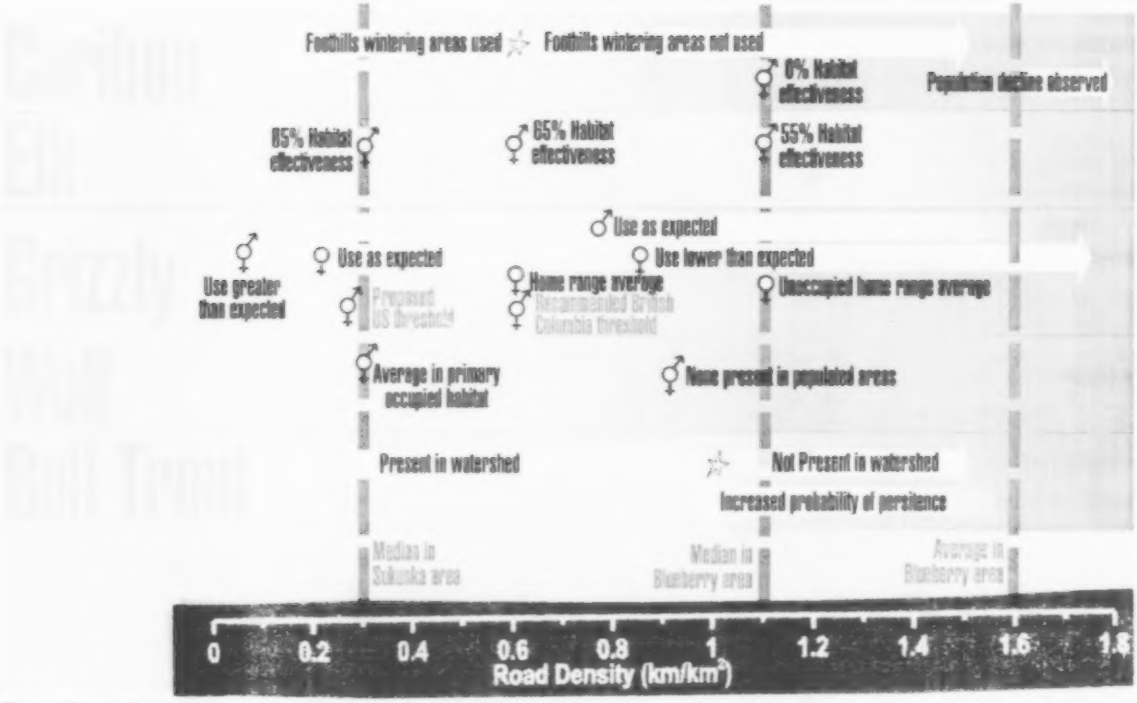


Figure 34. Documented access density effects for selected fish and wildlife species.

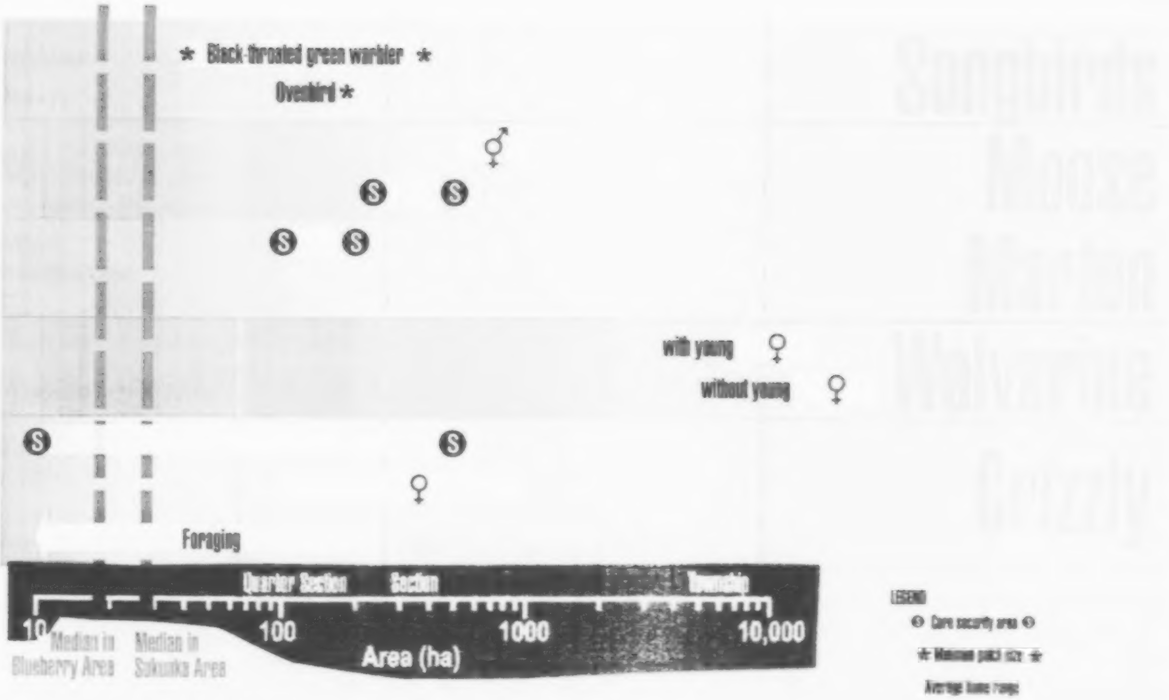


Figure 35. Documented core area, minimum patch size, and home range areas for selected wildlife species.

Table 10. Tiered threshold implementation in northeast British Columbia

	Threshold by Land and Resource Management Plan Designation		
Indicator	**Enhanced Resource Development Areas**	**General Resource Management Areas**	**Special Resource Management Areas**
Candidate Generalized Thresholds			
Landscape Road and Trail Density (open primary and secondary roads, truck trails, and designated ATV trails)	**Cautionary:** Median 0.6 km/km^2 (calculated for threshold analysis area)[1] **Target:** Median 1.0 km/km^2 (calculated for threshold analysis area)[1] **Critical:** Median 1.2 km/km^2 (calculated for threshold analysis area)[1]	**Cautionary:** Median 0.4 km/km^2 (calculated for threshold analysis area)[1] **Target:** Median 0.6 km/km^2 (calculated for threshold analysis area)[1] **Critical:** Median 0.9 km/km^2 (calculated for threshold analysis area)[1]	**Cautionary:** Median 0.2 km/km^2 (calculated for entire RMZ) **Target:** Median 0.3 km/km^2 (calculated for entire RMZ) **Critical:** Median 0.4 km/km^2 (calculated for entire RMZ)
Watershed Road and Trail Density (open primary and secondary roads, truck trails, and designated ATV trails)	**Cautionary:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 1.7 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 2.4 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)	**Cautionary:** Median 0.6 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 1.7 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)	**Cautionary:** Median 0.3 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 0.6 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)

Table 10 Tiered threshold implementation in northeast British Columbia (cont.)

Indicator	Threshold by Land and Resource Management Plan Designation		
	Enhanced Resource Development Areas	General Resource Management Areas	Special Resource Management Areas
Generalized Core Area (area outside 500 m buffer around high-use features, including primary and secondary roads, truck and ATV trails, wellsites, industrial, commercial, and recreational facilities, communities, and permanent residences)	**Cautionary:** 50% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1]. **Target:** 40% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1]. **Critical:** 20% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1].	**Cautionary:** 65% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1]. **Target:** 50% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1]. **Critical:** 40% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1].	**Cautionary:** 85% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ). **Target:** 75% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ). **Critical:** 65% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ).
Candidate Species-Specific Thresholds			
Woodland Caribou – Total Corridor Density (open primary and secondary roads, truck trails, designated ATV trails, pipeline and powerline rights-of-way, railways, and conventional cutlines)	**Cautionary:** Median 1.5 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 1.8 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 3.0 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 1.2 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 1.5 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 1.8 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 1 km/km^2 (calculated for entire RMZ). **Target:** Median 1.2 km/km^2 (calculated for entire RMZ). **Critical:** Median 1.5 km/km^2 (calculated for entire RMZ).

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[1] – Threshold analysis area includes all BSGS 1:20,000 map sheets intersected by the project plus immediately adjacent sheets, minimum 450 km^2

Thresholds provided in Table 10 are based on median values rather than average values used elsewhere. Road and trail frequency distributions were skewed in both the Blueberry and Sukunka Case Studies, and median values provided better estimates of central tendency than did average or mean values.

Analysis Area

Identification of appropriate analysis area (spatial boundaries) is a critical component of environmental assessment. Selection of a very large analysis area increases the likelihood that an effect will be judged to be of no concern because it is relatively small in comparison. In contrast, selection of a small study area prevents consideration of incremental and cumulative effects that are best evaluated over larger areas.

A map sheet-based approach is recommended for northeast British Columbia to simplify data collection and spatial analyses. TRIM II digital data are readily available from the provincial government and provide the most comprehensive and current information for this region. To be consistent, total road and trail density should be calculated for all BSGS 1:20,000 map sheets directly affected by the project and all adjoining sheets. This translates to a minimum of six map sheets covering a 450 to 500 km^2 area; this is consistent with landscape-level planning (MSRM 2002a) and sufficiently large to allow consideration of the 'big picture'. This scale is ecologically meaningful for the large, mobile animal species that are most susceptible to access-related cumulative effects.

An advantage of a map sheet-based approach is that it allows a regional database of land use features to be generated over time as a result of independent submissions by project proponents (Eccles et al. 1994). This is considered to be the most practical and economic method of generating the required database, since the incremental cost to each proponent would be low, and the most active development areas would be included at early stages.

The revegetation status of existing roads and trails should also be considered, because this is known to affect animal response (e.g., Mace et al. 1996). Roads and trails can be considered impassable if:

- woody vegetation greater than 1.5 m in height has become established (roughly 10 to 15 years post-construction in this area),
- the road has been reclaimed, or
- access control measures have been implemented, and no evidence of use is present.

For initial screening purposes, all roads and trails should be considered to be open, unless field data confirm that they are impassable. To allow this to be tracked, age and revegetation status should be added as attributes for each linear feature.

Candidate Threshold Derivation

The numerical values for generalized landscape thresholds provided in Table 10 were established as follows.

The Critical Threshold for special resource management areas (median <0.4 km/km^2) was set below the 0.6 km/km^2 threshold identified for persistence of the most sensitive species (caribou, grizzly bear, bull trout persistence; Figure 34). This critical threshold is defined to be protective of all species over the long-term. The Target Threshold for special resource management areas (median <0.3 km/km^2) was set to an average home range value known to be used by these sensitive species, which also reflects the proposed United States threshold for grizzly bear recovery (Figure 34). The Cautionary Threshold for special resource management areas (median <0.2 km/km^2) was arbitrarily set below the target threshold to ensure that enhanced protection measures are implemented at early stages of fragmentation. Use of the entire RMZ as the spatial boundary for these analyses is intended to ensure that assessment and management occurs at the largest practical scale.

The Critical Threshold for general resource management areas (median <0.9 km/km^2) was set at the midpoint between the Target Threshold and existing conditions in the Case Study areas. This threshold cannot be assumed to provide adequate protection for the most sensitive species over the long-term, but it appears to be sufficient to allow more tolerant species (elk, wolf) to persist. The Target Threshold for general resource management areas (median <0.6 km/km^2) was set to the threshold identified for persistence of the most sensitive species (caribou, grizzly bear, and bull trout persistence; Figure 34). This threshold represents the desired road and trail density in much of the region, and would trigger restrictive protection measures to reduce further fragmentation. The Cautionary Threshold for general resource management areas (median <0.4 km/km^2) was set to be consistent with the Critical Threshold for special management areas in order to ensure that enhanced protection measures are implemented at early stages of fragmentation.

The Critical Threshold for enhanced resource development areas (median <1.2 km/km^2) was set to reflect existing conditions in the Case Study areas. This threshold may not ensure persistence of the most sensitive species over the long-term (caribou, grizzly bear, and bull trout), but it appears to be sufficient to ensure persistence of most species of management concern. The Target Threshold for enhanced resource development areas (median <1.0 km/km^2) was set based on access density-core area relationships (Figure 30) to ensure persistence of a wide range of birds and mammals (Andren 1994). The Cautionary Threshold for enhanced resource development areas (0.6 km/km^2) was set to the threshold identified for persistence of the most sensitive species (caribou, grizzly bear, and bull trout; Figure 34). This threshold would trigger enhanced protection measures to reduce further fragmentation.

4.4.2.2 Watershed Road and Trail Density

Watershed road and trail density is an indicator of cumulative risk of erosion and peak flow. This indicator should be calculated for all subwatersheds directly affected by the project (i.e., all those in which roads, rights-of-way, or facilities would be constructed). Subwatersheds include drainages 50 to 500 km^2 in size based on the 1:50,000 British Columbia Watershed Atlas. For watershed analyses, linear features should be considered to be revegetated if complete vegetation cover is present over the entire right-of-way, and there is no evidence of use. The numerical values for generalized watershed thresholds provided in Table 10 were established as follows.

Candidate Threshold Derivation

The Critical Threshold for special resource management areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the Interior Watershed Assessment Process; (IWAP; BCF and BCE 1995b). This is considered to represent low risk of peak flow and surface erosion effects over the long-term. The Target Threshold for special resource management areas (median <0.6 km/km^2) was set at the 0.2 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects. The Cautionary Threshold for special resource management areas (median <0.3 km/km^2) was at the 0.1 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects.

The Critical Threshold for general resource management areas (median <1.7 km/km^2) was set at the 0.6 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with moderate risk of peak flow and surface erosion effects. The Target Threshold for general resource management areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the IWAP (BCF and BCE 1995b), to represent low risk of long-term watershed effects. The Cautionary Threshold for general resource management areas (median <0.6 km/km^2) was at the 0.2 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects.

The Critical Threshold for enhanced resource development areas (median <2.4 km/km^2) was set at the 0.8 to 0.9 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with high risk of peak flow and surface erosion effects. The Target Threshold for enhanced resource development areas (median <1.7 km/km^2) was set at the 0.6 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with moderate risk of peak flow and surface erosion effects. The Cautionary Threshold for enhanced resource development areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the IWAP (BCF and BCE 1995b), to represent low risk of long-term watershed effects.

4.4.2.3 Minimum Core Area

Minimum core area is a useful complement to road and trail density since it identifies areas with minimum human disturbance. Although the total area of remaining core could be accurately predicted from road and trail density in the Blueberry and Sukunka Case Studies, information on the location and size of these areas is important so that fragmentation of remaining core areas can be avoided or minimized wherever possible.

As with road and trail density, there have been considerable differences in core area calculations. A common approach is to include a 500 m zone of influence around all potential high use features. In northeast British Columbia, these are assumed to include: primary and secondary roads; truck trails passable by four-wheel drive; designated ATV/OHV trails; wellsites; industrial, commercial, and recreational facilities; and communities. To provide sufficient security, core area patches should meet minimum width and size criteria that reflect the desired level of protection and target management species.

Activity setbacks (buffers) are commonly used to avoid or reduce local project-specific effects (Axys 2001a, b; Appendix 1). Ideally, buffers used to calculate landscape and watershed scale indicators such as core area should be based on established setbacks to help integrate assessment and management at all scales.

Analysis Area

The same map sheet-based approach specified for road and trail density is also recommended for generalized core area analyses, i.e., all BSGS 1:20,000 map sheets directly affected by the project and all adjoining sheets. This translates to a minimum of six map sheets covering a 450 to 500 km^2 area.

Candidate Threshold Derivation

The numerical values for generalized landscape thresholds provided in Table 10 were established as follows.

The Critical Threshold for special resource management areas (>65% large core areas) was set above the 60% threshold calculated for boreal-ecotype woodland caribou and proposed for grizzly bear (Table 2). This conservative threshold is intended to represent the current level of uncertainty associated with this indicator, and the variable habitat suitability present in core areas. The Target Threshold for special resource management areas (>75% large core areas) was set in between proposed thresholds for grizzly bear recovery and the Critical Threshold. The Cautionary Threshold for special resource management areas (>85% large core areas) was set above thresholds for grizzly bear recovery.

The Critical Threshold for general resource management areas (>40% moderately large core areas) was set at the threshold calculated for interior habitat specialists (Table 2). The Target Threshold for general resource management areas (>50% moderately large core areas) was set at the observed 50% caribou threshold. The Cautionary Threshold for general resource management areas (>65% large core areas) was set to be consistent with the Critical Threshold for special management areas; this would initiate monitoring to determine whether this threshold can be relaxed while still providing adequate long-term protection.

The Critical Threshold for enhanced resource development areas (>20% small core areas) was set at the midpoint of the minimum habitat thresholds identified by Andren (1994). The Target Threshold for enhanced resource development areas (>35% small core areas) was set above the minimum habitat thresholds predicted for habitat generalists (Table 2). The Cautionary Threshold for enhanced resource development areas (>50% small core areas) was set at the observed boreal-ecotype caribou and above the interior species threshold to provide additional protection and to be consistent with the Target Threshold for general resource management areas.

4.4.2.4 Species-Specific Thresholds

All three generalized landscape and watershed-based thresholds are intended for application throughout the region. In areas with local sensitivity ('hot spots'), species-specific thresholds will likely be required to provide enhanced protection and supplement the generalized land use and habitat thresholds.

Specific candidate thresholds developed for boreal-ecotype woodland caribou are provided in Table 13. This species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance for reasons described below. Caribou population declines have been documented in other areas of western Canada with development footprints similar to those that currently exist in northeast British Columbia.

Generalized road and trail density thresholds included only potential high-use features because access effects on most wildlife species appear to be related to traffic volumes, out-of-vehicle activity, and predation rather than the physical presence of the feature (Appendix 1). However, reduced caribou use has been documented adjacent to linear corridors independent of the level of activity in some (Dyer 1999), but not all areas (Oberg 2001). Although no clear relationship has been demonstrated, linear corridors may increase predation by providing packed travel routes for wolves, thus increasing their search efficiency and range (Bergerud et al. 1984). This may be especially significant for woodland caribou. In north central Alberta, wolf predation rates for caribou were higher in proximity to linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000), but wolves avoided these features in west central Alberta (Kuzyk 2002). Research will be required to determine actual response of boreal- and northern-ecotype caribou in northeast British Columbia.

Candidate thresholds are intended to be protective and are set at or below the lowest detected effect level identified for this species (Appendix 1). Given the scientific uncertainty that currently exists, the candidate woodland caribou thresholds include all linear-rights-of-way greater than 3 m in width. Passable features of this size could increase winter predation and harassment risk from wolves and snow machines.

Candidate Threshold Derivation

The Critical Threshold for special resource management areas (median <1.5 km/km^2) was set below the 1.8 km/km^2 threshold identified for boreal-ecotype caribou (Table 2). The Target and Cautionary Thresholds for special resource management areas (respectively median <1.2 km/km^2 and <1 km/km^2) were arbitrarily set below this threshold to ensure that monitoring and restrictive measures are implemented at early stages of development in designated caribou range.

The Critical Threshold for general resource management areas (median <1.8 km/km^2) was set at the persistence threshold identified for boreal-ecotype caribou (Table 2). The Target and Cautionary Thresholds for special resource management areas (respectively median <1.5 km/km^2 and <1.2 km/km^2) were arbitrarily set to be protective and consistent with special resource management area thresholds.

The Critical Threshold for enhanced resource development areas (median <3 km/km^2) was liberally set to the maximum value where woodland caribou could persist (Table 4, Appendix 1) because existing corridor density likely exceeds this threshold in much of the region. The Target Threshold for enhanced resource development areas (median <1.8 km/km^2) was set at the persistence threshold identified for boreal-ecotype caribou (Table 2). The Cautionary Threshold for enhanced resource development areas (median <1.5 km/km^2) was set to be consistent with other resource management areas.

4.4.3 Economic and Ecological Implications

The land use footprint in some areas of northeast British Columbia currently exceeds one or more candidate thresholds. Regional stakeholders will understandably be concerned about the effects of threshold implementation and will need to be convinced that they provide an appropriate balance between environmental protection and economic development.

Formal evaluations are recommended to allow government, industry, and other regional groups to understand the implications of cumulative effects assessment and management. A variety of integrated management models are available for such a task. In a recent review of predictive modelling tools, the ALCES landscape simulator was concluded to be the most comprehensive because it incorporates all potential land uses. Its greatest strength was considered to be its ability to incorporate user-defined changes so that the effect of various development scenarios and management options can be visualized (Salmo et al. 2001). ALCES was modified and applied in the Blueberry Case Study specifically to evaluate its suitability for northeast British Columbia.

This brief overview identifies some challenges that will need to be explicitly considered by regional resource managers and users prior to threshold implementation. Current 'Landscape road and trail density' exceeds the candidate Cautionary, Target, and Critical thresholds in the overall Blueberry study area. In the Jedney RMZ, the candidate Target Threshold is currently exceeded, and the candidate Critical Threshold would be exceeded by 2010 if historical road and trail construction trends continue.

One hundred year simulations were conducted with ALCES to visualize road and trail growth between 1950 and 2050 (Figure 36). Actual development rate was used between 1950 and present. Three future scenarios were modelled: Low growth (line 1 = actual 1950 to 1998 average development rate), Moderate growth (line 2 = actual 1970 to 1998 average development rate), and High growth (line 3 = actual 1970 to 1998 average development rate plus 20%).

The Blueberry Case Study area is extensively developed at present, and the projected future development footprint was not highly sensitive to the growth rate used. These projections indicate that restrictive protection measures should be applied in the near future to reduce further cumulative effects risk in the Jedney Enhanced Resource Development RMZ.

As noted previously, forest fragmentation is at earlier stages in the Sukunka Case Study area, and candidate Target and Critical thresholds are not currently exceeded. If historical road and trail construction trends continue, the candidate Target and Critical thresholds would be surpassed by 2024, and 2030, respectively.

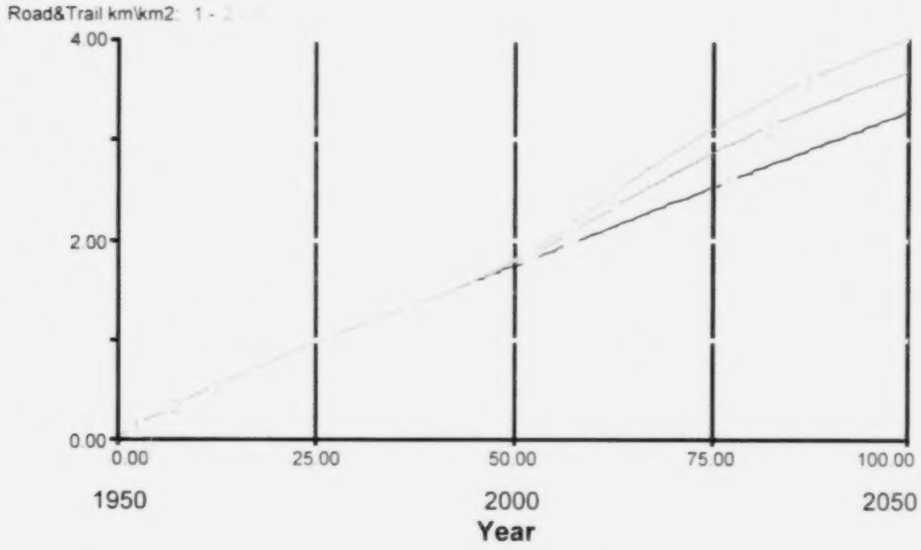

Figure 36. Projected road and trail density in the Blueberry Case Study area, 1950 to 2050 (1 = Low growth scenario; 2 = Average growth scenario; 3 = High growth scenario; road and trail density (km/km^2) on y-axis).

The potential benefit of enhanced and restrictive environmental protection measures in the Blueberry study area was also modelled with ALCES. Projected trends in future road and trail density with and without restrictive protection measures are depicted in Figure 37 (note change in scale on y-axis from Figure 36).

The simulation in Figure 37 assumed that restrictive protection measures were implemented in 1950 as development in the Blueberry Case Study area began. The simulation shows that restrictive environmental protection measures such as cooperative road planning, aggregated cutblocks, and multiple well pads can substantially slow increases in road density.

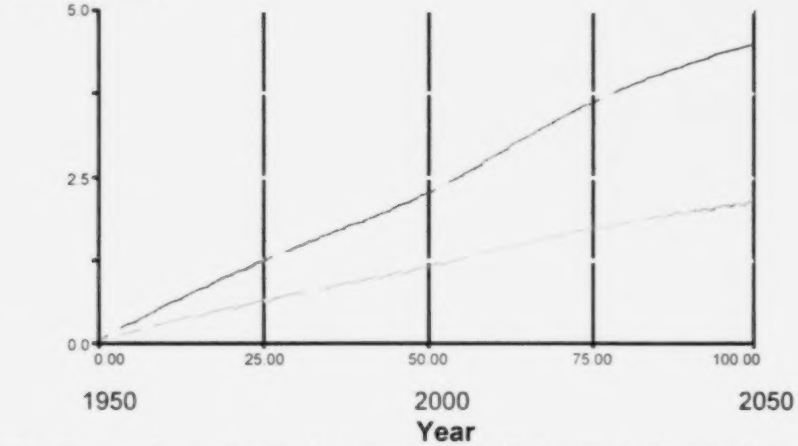

Figure 37. Comparison of projected road and trail density in the Blueberry Case Study area without (#1) and with (#2) restrictive protection measures (road and trail density (km/km^2) on y-axis).

The simulated effect of these same enhanced and restrictive protection measures on woodland caribou habitat effectiveness is depicted in Figure 38. The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat; Section 3.3.2). This simulation also assumed that restrictive protection measures were implemented in 1950 as development in the Blueberry Case Study area began.

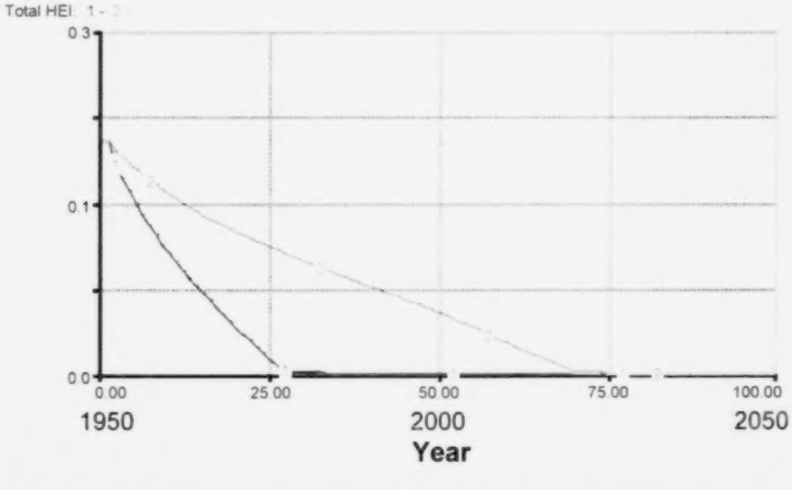

Figure 38. Comparison of projected caribou habitat effectiveness in the Blueberry Case Study area without (#1) and with (#2) restrictive protection measures (Habitat Effectiveness Index on y-axis).

Figure 38 demonstrates that enhanced and restrictive protection measures that reduce the growth of the access corridor and clearing network can reduce cumulative effects risk. This is particularly true for species such as woodland caribou that are extremely sensitive to edge effects. The Sukunka Case Study area provides a regional example of these benefits. Low-impact seismic programs have been required in this area since the early 1990's; this has reduced the rate of habitat fragmentation and disturbance relative to the Blueberry Case Study area (Section 3.2.1)

4.4.4 Project Analysis, Reporting, and Review

In northeast British Columbia, application of tiered thresholds would provide the opportunity to:

- encourage performance and results-based management,
- clearly link management actions with cumulative effects indicators,
- provide the flexibility required for different land management regimes and ecological settings, and
- provide the flexibility necessary for the full spectrum of development proposals (i.e., simple, normal, and complex).

Implementation options span the range from a primary government role to a primary land user role. Past experience demonstrates that the active support and participation of both groups will be needed. The implementation approach presented here is intended to provide an example of how cumulative effects indicators and thresholds can be incorporated in the existing project review process. This approach assumes the following:

- all resource managers and users share the responsibility for assessment and management of cumulative effects,
- the level of assessment, review, and environmental protection will be related to the potential risk of adverse cumulative effects,
- management actions will be explicitly linked to thresholds so that resource users can choose the most effective method of achieving them,
- resource managers are responsible for providing clear guidance on the calculation and application of tiered thresholds, for providing the information necessary to complete these evaluations in a timely and efficient manner, and for ensuring that rules are consistently and fairly applied,
- proponents are responsible for defining a project's contribution to cumulative effects in the land management area in which the activity is proposed and for participating in cooperative regional initiatives, and
- cooperative research and monitoring will be conducted in selected areas to provide information necessary to refine established thresholds and management actions.

In northeast British Columbia, project proposals are likely to undergo one of three classes of regulatory review:

Routine Review:	Simple or normal proposals with limited potential for significant adverse cumulative effects.
Enhanced Review:	Simple or normal proposals in sensitive areas or those with some potential for significant adverse cumulative effects.
Complex Review:	Complex proposals with high potential for significant cumulative effects.

The desired attributes of indicators and thresholds for each review class were described in Section 2.4 (Table 6). Table 11 provides additional information on how project analysis, reporting, and review requirements could be integrated with prescribed management actions for each class of review. This table also identifies the incremental cost of cumulative effects threshold implementation. A decision tree is provided in Figure 39 to demonstrate how thresholds can be applied by proponents and regulators for cumulative effects assessment and management.

4.4.4.1 Routine Review: Cumulative Effects Screening

'Cumulative Effects Screening' would be conducted for simple or normal projects with limited potential for significant adverse cumulative effects (i.e., outside sensitive areas such as designated caribou habitat). This is expected to include most applications made in the region.

Cumulative Effects Screening would require proponents to include calculations of the generalized landscape and watershed indicators provided in Table 10 with their applications. These calculations would use standardized methods and readily available public data to allow submissions to be quickly and economically prepared. Calculations would identify the current value for each indicator and the projected value with the addition of the proposed project, and relate these to the thresholds for the land management area(s) in which the project is located. This would enable proponent and regulators to explicitly assess the potential for significant adverse effects.

Management Actions

If Cumulative Effects Screening concludes that all indicators will be within established Cautionary Thresholds, best environmental management practices would apply and no further management or review action would be required (green pathway on Figure 39).

If Cumulative Effects Screening concludes that one or more indicators will exceed Cautionary Thresholds, but be within Target Thresholds, enhanced environmental management practices would be implemented for the project and cooperative monitoring would be initiated in the appropriate land management area(s) (blue pathway on Figure 39). Enhanced practices could include specific measures to reduce wellsite size, right-of-way width, or line-of-sight.

Table 11. Review and management actions associated with tiered thresholds.

Type of Project	Management Action		
	Project Review		Protection Measures
	Submission Requirements	Incremental Cost	
Cumulative Effects Screening (Routine Review)	1. Calculate generalized landscape and watershed indicators with project using standard methods and public data and compare to generalized thresholds.	<$10,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to conduct enhanced Cumulative Effects Evaluation. Project automatically moved to enhanced or detailed review where Critical Threshold exceeded.
Cumulative Effects Evaluation (Enhanced Review)	1. Calculate generalized landscape and watershed indicators with project using standard methods and public data and compare to generalized thresholds. 2. Provide enhanced evaluation using site-specific data or species-specific thresholds and evaluations.	$10,000 - $100,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to implement field studies to validate road, trail, and cutline status and use. Project rejected or moved to detailed review where Critical Threshold exceeded; proponent option to identify offsite compensation or cooperative programs to achieve no net loss.
Cumulative Effects Assessment (Complex Review)	1. Prepare General Development Plan for proposed activities. 2. Prepare Impact Assessment to identify significant fish and wildlife habitats and other resource values; include detailed cumulative effects assessment using appropriate modelling and assessment techniques for focus species. 3. Conduct landscape simulations to evaluate risk and uncertainty where appropriate.	>$100,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to implement field studies to validate land use and focus species status. Restrictive Environmental Protection Measures become base case in Special Management Areas (e.g., Besa-Prophet Pre-Tenure Plan, MSRM 2002b). Project rejected where Critical Threshold exceeded; proponent option to identify offsite compensation or cooperative programs to achieve no net loss.

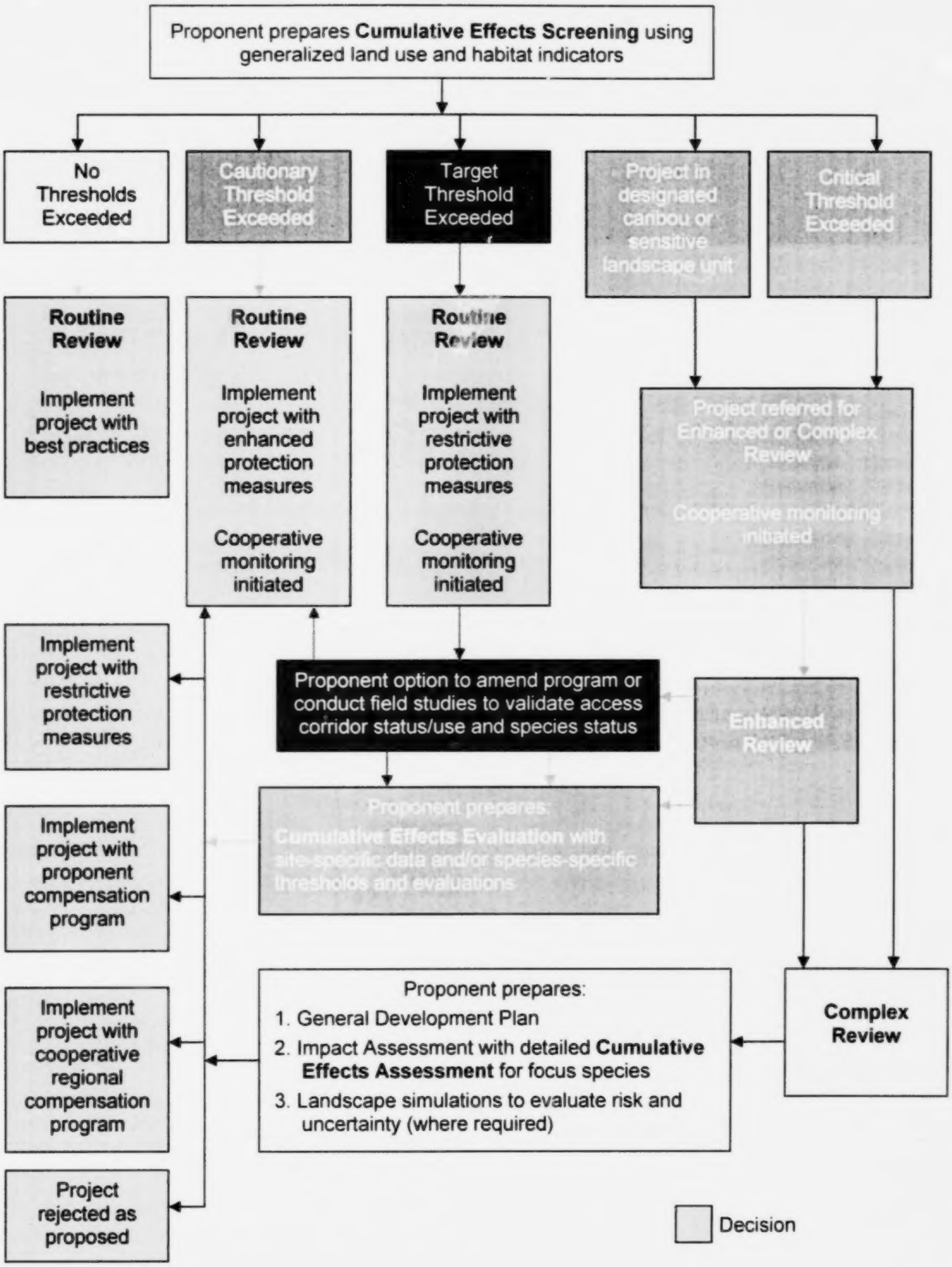
Proponent prepares **Cumulative Effects Screening** using generalized land use and habitat indicators
No Thresholds Exceeded
Cautionary Threshold Exceeded
Target Threshold Exceeded
Project in designated caribou or sensitive landscape unit
Critical Threshold Exceeded
Routine Review
Implement project with best practices
Routine Review
Implement project with enhanced protection measures
Cooperative monitoring initiated
Routine Review
Implement project with restrictive protection measures
Cooperative monitoring initiated
Project referred for Enhanced or Complex Review
Cooperative monitoring initiated
Implement project with restrictive protection measures
Proponent option to amend program or conduct field studies to validate access corridor status/use and species status
Enhanced Review
Implement project with proponent compensation program
Proponent prepares:
Cumulative Effects Evaluation with site-specific data and/or species-specific thresholds and evaluations
Implement project with cooperative regional compensation program
Proponent prepares:
1. General Development Plan
2. Impact Assessment with detailed **Cumulative Effects Assessment** for focus species
3. Landscape simulations to evaluate risk and uncertainty (where required)
Complex Review
Project rejected as proposed
Decision

Figure 39. Decision tree for tiered threshold implementation.

If Cumulative Effects Screening concludes that one or more indicators will exceed Target Thresholds, but be within the Critical Threshold, restrictive environmental management practices would be implemented for the project and cooperative monitoring would be initiated in the appropriate land management area(s). The proponent could choose to conduct field studies to update the readily available public database and improve the accuracy of the indicator calculations by identifying impassable or low-use features that could be removed from subsequent calculations. This would remove some of the inherent conservatism of this approach and would frequently revise indicators downward to values below established thresholds (purple pathway on Figure 39).

Enhanced and restrictive management practices include project initiatives such as alternate routing and siting, or avoidance of core areas. They also include joint project and regional initiatives such as cooperative road planning designed to mitigate or compensate cumulative effects. Cooperative effects management options are discussed in more detail in Section 4.5 of CEAMF Volume 1.

If Cumulative Effects Screening concludes that one or more indicators will exceed the Critical Thresholds, the project would automatically be put through enhanced or detailed review (Table 11; orange pathway on Figure 39).

4.4.4.2 Enhanced Review: Cumulative Effects Evaluation

For simple or normal projects in sensitive areas with some potential for significant adverse cumulative effects (e.g., 'hot spots' such as designated caribou habitat or Landscape Units), Cumulative Effects Screening would be supplemented with site-specific data and/or species-specific evaluations. These 'Cumulative Effects Evaluations' would consider the availability of sensitive habitat, or the actual status and use of roads and trails. This would allow simplifying and conservative assumptions to be modified where appropriate, using data specific to the proposed area of activity.

Enhanced Cumulative Effects Evaluation would also use standardized methods and protective species-specific thresholds (e.g., candidate caribou thresholds in Table 10) applicable to the land management area(s) in which the activity is proposed.

Management Actions

If Cumulative Effects Screening and Evaluation concludes that all indicators will be within established landscape, watershed, and species-specific Cautionary Thresholds, best environmental management practices would apply and no further management or review action would be required (identical to green pathway on Figure 39, but with species-specific thresholds considered).

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed Cautionary Thresholds, but be within Target Thresholds, enhanced environmental management practices would be implemented for the project (orange pathway on Figure 39). Enhanced practices include specific measures to reduce wellsite size or right-of-way width or manage access.

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed Target Thresholds, but be within the Critical Threshold, restrictive environmental management practices would be implemented for the project (orange pathway on Figure 39). Restrictive practices include off-site compensation to achieve no net access creation in the land management area(s) in which the activity is proposed. They also include joint project and regional initiatives discussed in more detail in Section 4.5 of CEAMF Volume 1.

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed the Critical Thresholds, the project would be subject to detailed review (yellow pathway on Figure 39).

4.4.4.3 Complex Review: Cumulative Effects Assessment

Detailed 'Cumulative Effects Assessments' would continue to be applied to large, reviewable projects, as well as to smaller projects in sensitive or specially designated areas such as the Muskwa-Kechika Special Management Area.

The Cumulative Effects Assessment would be based on a General Development Plan (OGC 2002) or Development Plan (MSRM 2002b), and include standardized analysis for generalized landscape and watershed thresholds along with detailed, species-specific analyses (Table 11, Figure 39). These could include habitat availability and effectiveness, core security analyses, and friction models to examine critical movement corridors (Salmo et al. 2001). Population viability and landscape level simulation models such as ALCES could also be applied to allow risk and uncertainty to be formally evaluated. Landscape simulations could examine the range of natural variability, extirpation risk, and conservation area design.

Management Actions

Review decisions and associated management actions for detailed Cumulative Effects Assessment would be similar to those described above for routine and enhanced reviews (Table 11; Figure 39). In Special Resource Management Areas, restrictive protection measures would become the minimum requirement.

The proposed project would be rejected if one or more Critical Thresholds are exceeded and an acceptable project-specific or cooperative no net loss compensation program cannot be identified.

4.4.5 Data Needs

Publicly available land use and resource data for northeast British Columbia are more comprehensive than those found in many other jurisdictions. Nevertheless, the current database discourage routine consideration of cumulative effects because:

- proponent access to government TRIM II digital data is restricted and the time required to negotiate access is too long for routine and enhanced project review,
- insufficient information is provided with TRIM II digital data to determine current disturbance feature status and use intensity,
- accurate terrestrial and aquatic habitat maps are not available for all areas, and existing forest cover data increase the cost and duration of cumulative effects evaluations and assessments with questionable gains in accuracy,
- TRIM II data are not regularly updated to reflect recent land use,
- TRIM II data include numerous watercourses that do not actually exist in the field, thereby reducing the utility of watershed indicator evaluations, and regional data on fish and wildlife species abundance and distribution are limited.

The threshold implementation approach described here will require a common source of easily available data that is regularly updated and can be readily accessed and used by regulators, proponents, and other interested groups and individuals. This database will require time and resource commitment to be developed.

Although the government must ultimately be responsible for database maintenance, regardless of who is assigned that task, the approach described here will streamline database development by using proponent submissions to incrementally build and update it. To be effective, this will require standardized data sharing and access protocols as well as standard analysis and reporting methods.

4.4.6 Pilot Study

Available literature and experience in other jurisdictions indicates that development and implementation of tiered ecological thresholds is a practical and effective method for assessing and managing cumulative effects. This report has provided a suite of recommended ecological indicators and candidate thresholds in northeast British Columbia. It has also described an approach for threshold implementation using the existing resource management and review process.

This information provides a foundation for threshold development and implementation. However, it is impractical to assume that this can immediately be applied to the entire region. The 'adaptive management' process originally conceived by Holling (1978) suggests that proposed management actions should be rigorously tested before they are widely applied.

A pilot study is recommended to test the candidate thresholds and implementation process and ensure that they provide an appropriate balance between environmental protection and socio-economic interests, i.e., they reflect 'acceptable change' as defined by regional stakeholders. Stakeholders who will be affected by threshold implementation should be involved in designing and evaluating the pilot. This will allow the ecological, economic, and social implications of threshold implementation in northeast British Columbia to be explicitly considered.

Two pilot study areas are proposed for consideration. Both are located in Enhanced Resource Development Areas that have elevated risk of cumulative effects because they have been moderately to highly disturbed and provide known habitat for boreal- and northern-ecotype caribou. As demonstrated in the Case Studies, this species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance. Both areas have existing data that can be used to enhance our understanding of ecological response to combined natural and human disturbance and to test management actions that will effectively and practically address cumulative effects.

The two candidate areas are:

> The western half of the **Jedney Enhanced Resource Development RMZ** located immediately east of the Alaska Highway in the Fort St. John LRMP area. Approximately one-third of this area was included in the Blueberry Case Study area. This area provides year-round habitat for boreal-ecotype woodland caribou, and is known to provide year-round habitat for an undetermined number of woodland caribou. Both boreal- and northern-ecotypes may be present. It was excluded from the Blueberry Case Study due to a lack of historical data, but the results of the Case Study would be directly applicable. Intensive monitoring of the caribou herd and validation of land use features and habitat would be required.
>
> A portion of the **Etsho Enhanced Resource Development RMZ** located east of Fort Nelson. This area provides year-round habitat for a boreal-ecotype caribou herd. Collection of detailed habitat use data through GPS telemetry was initiated by Slocan Forest Products Ltd. in 2000 and is currently ongoing. Collection of wolf and black bear GPS telemetry data has also recently been initiated as a component of the caribou research project. These data have not yet been analyzed, but would provide valuable information on the caribou habitat selection as well as their response to land use features, human activity, and predators. The benefits of enhanced and restrictive protection measures could also be tested.

SECTION 5: REFERENCES

CUMULAT SME MEWORK (CEAMF) STUDY

5. REFERENCES

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APPENDICES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY

Cumulative Effects Assessment and Management
for
Northeast British Columbia

Volume 2
Cumulative Effects Indicators, Thresholds, and Case Studies

Appendix 1
Cumulative Effects: Sources, Indicators, and Thresholds

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January, 2003

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GLOSSARY

Access corridor – a linear feature created by humans (road, trail, pipeline, powerline, railway line, cutline) that may be used by pedestrians, vehicles, hunters, anglers, or animal predators.

ALCES – 'A Landscape Cumulative Effects Simulator' computer model used to forecast changes in landscape patterns and wildlife habitat. This simulator integrates four submodels (habitat availability, population, land use, and natural disturbance) and considers all land use activities likely to occur in the region. It includes both aquatic and terrestrial indicators and is able to incorporate random events such as fire.

Barrier – a barrier is present when it is not possible for animals to move across a corridor, and the habitat on either side of the corridor becomes isolated (e.g., a busy highway is a barrier for small ground-dwelling insects)

Biodiversity – the diversity of plants, animals, and other living organisms in all their forms and levels of organization (BCF and BCE 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Biogeoclimatic zone – a geographic area having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macro-climate (BCF and BCE 1995a).

Cautionary threshold – a threshold established to indicate that additional or more intensive monitoring is required to provide sufficient local data to confirm scientific predictions of both target and critical thresholds.

CEAM – Cumulative Effects Assessment and Management framework consisting of an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley; windrow, aeolian ridge) or as the result of human disturbance (e.g., roads, cutlines).

Critical threshold – a science-based target reflecting the continuous maximum amount of stress that a sensitive ecosystem or species can support without sustaining long-term harm. This may incorporate economic and social values to determine the acceptable magnitude of change, risk of long-term damage, or level of protection required.

Cumulative effects – changes to the environment caused by collective past, present, and future human actions; most result from the combined effects of simple, routine activities and projects.

DC – Disturbance Coefficient; an index assigned to each feature or activity type that rates the degree to which the disturbance zone of influence remains effectively useable by the species. Ratings are on a scale of 0 to 1 and are used to calculate habitat effectiveness.

Density-dependent – factors that affect population growth and parameters in relation to as animal abundance. These depress population growth as animal abundance increases, and increase growth as animal abundance decreases. Examples include food availability and quality. Predation may be density-dependent or –independent.

Density-independent – factors that affect population growth and parameters regardless of animal abundance. Examples include natural environmental disturbances such as fire, floods, or severe weather. Predation may be density-dependent or –independent.

Disturbance – a natural or human action that affects physical, chemical, or biological conditions.

Disturbance feature – a corridor or patch created by natural random events (e.g., burn or flood) or human action (e.g., cutblock, facility, community, road).

Disturbance trajectory – the calculated or predicted rate of natural or human disturbance.

Drainage - a subset of a watershed, generally less than 1,000 km^2 in size.

Early seral – forest that are younger than 40 years old (BCF and MELP 1999b).

Ecological resilience – the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996).

Ecological sink – an area with degraded habitat that has lower survival (or higher mortality) rates, causing local population declines. Although individual animals may continue to use this area, it creates a net loss to the population that may not be detectable for several generations.

Edge area - the area bordering patches and corridors where abiotic conditions (e.g., moisture, light, temperature, wind regimes) and biotic conditions (e.g., predation, mortality, competition, vegetation diversity and structure, species diversity and abundance) may be altered. Examples include the intersection between a cutblock and forest or a trail and native grassland.

Filter or porous barrier – a type of corridor across which some movement occurs but the rate of movement is less than through intact habitat (e.g., a busy highway is a porous barrier for large mobile wildlife like deer).

Fragmentation – the process of losing habitat continuity through temporary or permanent conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). Three general effects result from habitat fragmentation: (1) original habitat is lost, (2) remaining habitat patches decrease in size, and, (3) patches become increasingly isolated from one another.

Habitat – the environment in which an organism or biological population lives or grows.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest regrowth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production; introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat availability – the amount of usable habitat accessible to a particular species.

Habitat capability – the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999).

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness for that species.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and regrowth is not allowed to occur (e.g., construction of a city, highway or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Habitat suitability – the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (RIC 1999).

Habitat unit – a defined terrestrial or aquatic unit with consistent abiotic and biotic conditions.

Hazard level – the risk of an adverse cumulative hydrological effect defined by the British Columbia Interior Watershed Assessment Procedure (IWAP; BCF and BCE 1995b, BCF 1999).

Human activity – all forms of human actions including land conversion and disturbance, damming, water withdrawal, pedestrian, vehicle and aircraft movements, harassment, harvest, and contaminant input.

Index or metric – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator – a surrogate measure used to represent or monitor the condition of an abiotic or biotic resource. May be a representative species, an outcome, or an input.

Interior area – also referred to as core area in this report. Interior areas are those beyond the influence of edge effects.

IWAP – Interior Watershed Assessment Procedure; a method developed by the provincial government to help forest managers understand the type and extent of current water-related problems in a watershed, and to recognize the implications of proposed activity in that watershed (BCF 1999).

Juvenile – an individual age 1 or older that has not reached maturity.

Landscape – an area of tens to hundreds of square kilometres that includes one dominant background ecosystem. Northeast British Columbia consists of a number of landscape types including the forest landscape, the agricultural landscape, and the alpine/subalpine landscape.

Local population - A breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Lowest observed effect level – concept from the field of ecotoxicology that represents the lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms compared to the controls. Also called lowest observed adverse effect level (LOAEL). This concept is also applicable to behavioural, physiological, and population response.

LU – Landscape Unit; an area of land and water used for long-term planning of resource management activities according to the *Forest Practices Code of British Columbia Act*. It may be used for designed strategies and patterns for landscape level biodiversity and for managing other forest resources (BCF and MELP 1999b).

LRMP – Land Resource Management Plan; a plan approved by the provincial government that establishes direction for land use and specifies broad resource management objectives and strategies.

Matrix – the dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Mature growth/mature seral – forests greater than a specified age (generally >80 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Metapopulation - a population of populations. This represents an abstraction of the population concept to a higher level. Metapopulations generally consist of a group of interacting but spatially discrete or isolated populations, subpopulations, or stocks. These subunits are linked by drainage networks but movement between subunits is infrequent and typically takes place across unsuitable habitat or over great distances (Hanski and Gilpin 1991; Dunham and Rieman 1999). An example of a fish metapopulation is a group of isolated headwaters populations found in the same watershed.

MSRM - British Columbia Ministry of Sustainable Resource Management

Natural disturbance type – an area characterized by a natural disturbance regime. The provincial government has established five natural disturbance types for managing biological diversity according to the *Forest Practices Code of British Columbia Act* (BCF and BCE 1995a; BCF and MELP 1999b).

OGC – British Columbia Oil and Gas Commission.

Old growth/old seral – forests greater than a specified age (generally >100 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches can occur naturally (e.g., sloughs, burns) or as the result of human disturbance (e.g., farmyards, wellsites, clearcuts).

Population – a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population limiting factors – processes that quantifiably affect the population rate-of-increase. Responsible for inducing year-to-year changes in animal abundance (Messier 1991).

Population regulating factors – density-dependent processes that ultimately keep populations within normal density ranges. These are a subset of limiting factors and predictably depress population growth as animal abundance increases (Messier 1991).

Reach – a defined watercourse channel section, tens to thousands of meters in length, with relatively consistent channel morphology, hydrology, and water chemistry.

Regional - an area more than hundreds of square kilometres that incorporates several landscapes.

Riparian - the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995c; BCF and MELP 1999b).

Riparian clearings - cleared areas within 15 m of a waterbody, including linear corridors, communities and residences, industrial and commercial facilities, cutblocks, and agricultural fields.

Riparian roads - roads and trails within 100 m of a waterbody.

RMZ – Resource Management Zone; defined subdivisions of an approved LRMP that have unique sets of resource values, objectives to maintain or enhance those values, and a number of strategies to be implemented to achieve those objectives. These provide geographically-focused, strategic direction (Fort St. John LRMP 1997).

Seral stage – the stages of natural ecological succession of a plant community, for example from young through mature to old stage (BCF and BCE 1995a).

Stream crossing - a road, trail, pipeline, powerline, railway line, or cutline crossing of a watercourse.

Subpopulation - a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Subwatershed - a subset of a watershed, generally less than 1,000 km^2 in size.

Target threshold – a politically-defined goal reflecting the optimum amount of stress on the system. This threshold is more protective than the critical threshold to provide a margin of safety. A target threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

Threshold – a point at which a resource changes to an unacceptable condition, with acceptability defined either from an ecological or social perspective.

Viable population – a self-sustaining population with a high probability of survival despite the foreseeable effects of demographic, environmental, and genetic stochasticity and of natural catastrophes (BCF and BCE 1995a).

Waterbody – a specific aquatic basins or channel (lake, pond, wetland, river, or stream).

Watercourse – a specific flowing channel (river or stream).

Watershed – a large drainage area, generally 1,000 to 10,000 km^2 in size, which flows directly into a large river such as the Peace River.

WHA – Wildlife Habitat Area contain critical habitat elements for one or more species of Identified Wildlife. These areas are mapped and approved by the Chief Forester and WLAP according to the *Forest Practices Code of British Columbia Act.*

WLAP – British Columbia Ministry of Water, Land and Air Protection.

ZOI – Zone of Influence; the distance to which a species is affected by an activity or disturbance.

1. INTRODUCTION

The British Columbia Oil and Gas Commission (OGC) established an environmental fund to address environmental effects associated with oil and gas development. In 2001, cumulative effects was one of three research envelopes for which funding was provided. Salmo Consulting Inc. (Salmo), Diversified Environmental Services (Diversified), GAIA Consultants Inc. (Gaia), and AXYS Environmental Consulting Ltd. (Axys), received funding under the cumulative effects research envelope to undertake two Case Studies in northeast British Columbia. The Case Studies were designed to test and develop approaches for assessing and managing cumulative effects in northeast British Columbia.

This report includes one of the components of the Case Studies, a literature review of ecological indicators and thresholds relevant to fish and wildlife management. Four main types of indicators and thresholds can be identified: Physical and Chemical, Ecological, Land Use, and Social. This review is largely restricted to ecological and land use indicators and thresholds, the classes of most direct relevance to fish and wildlife management. Physical and chemical thresholds are briefly discussed, but a review of social indicators is beyond the scope of this project.

As follows, this report is divided into six main sections with the detailed Case Studies provided in subsequent appendices.

Section 2. Cumulative Environmental Effects

- explains key concepts relevant to cumulative effects assessment and management, and
- describes the four main types of cumulative effects: habitat alteration and loss, barriers to movement, direct and indirect mortality, and disturbance.

Section 3. Management Thresholds

- explains key concepts relevant to thresholds.

Section 4. Ecological Indicators and Thresholds

- summarizes literature on four types of ecological indicators: habitat, population, biodiversity, and risk-based.

Section 5. Land Use Indicators and Thresholds

- summarizes literature on five types of land use indicators: human activity, human-caused mortality, access density, cleared or disturbed area, and watershed assessments.

Section 6. Species-Specific Indicators and Thresholds

- summarizes literature for three focus species: bull trout, grizzly bear, and woodland caribou.

Section 7. Indicators for Northeast British Columbia

- identifies recommended indicators for cumulative effects assessment and management in the region.

Section 8. References

2. CUMULATIVE ENVIRONMENTAL EFFECTS

Cumulative effects are environmental changes caused by combined past, present, and future human actions. Over the last twenty years, cumulative environmental effects have received increasing interest; it is now recognized that the combined effects of unrelated individual activities can be different in nature or extent from the sum of the effects of each individual activity (Contant and Wiggins 1991; FEARO 1994; Riffell et al. 1996).

2.1 LANDSCAPE ECOLOGY

Concepts and terms developed for the fields of landscape ecology and conservation biology provide a foundation for evaluating cumulative effects on fish and wildlife habitat and populations. The following discussion is adapted from Jalkotzy et al. (1998).

2.1.1 Terrestrial Habitat

The land we live on is a **mosaic**, or a pattern comprised of three basic units: patches, corridors, and the matrix. These three landscape elements may be natural or of human origin. The **matrix** is the dominant background ecosystem or land use type in the mosaic. Within this matrix, **patches** and **corridors** are reasonably uniform areas and linear features that differ from their surroundings. The matrix and the type and arrangement of patches and corridors in that matrix determine the suitability of the landscape mosaic for different species.

Scale is an important consideration for cumulative effect evaluations. A **landscape** represents an area of tens to hundreds of square kilometres that includes a particular mosaic. A **region** may contain many landscapes but may not necessarily have a repeating pattern of landscapes or landscape elements. At this larger scale, the type and spatial arrangement of landscapes determines the region's suitability for different species.

There are two main landscape types in northeast British Columbia. In the **forest landscape** (Figure 1), there are treed patches of variable size, age, structure, and species composition. Unforested openings associated with waterbodies, bedrock, and low-growing vegetative cover are also present. Within this matrix, there are human-disturbed patches such as wellsites and cut blocks, as well as disturbance corridors like roads, trails, and powerline and pipeline rights-of-way. The landscape outside forested areas (the **agricultural landscape**, Figure 2) is a human-dominated matrix with remnant areas of native trees, shrubs, and grasses in patches and along corridors (e.g., windrows or along road ditches).

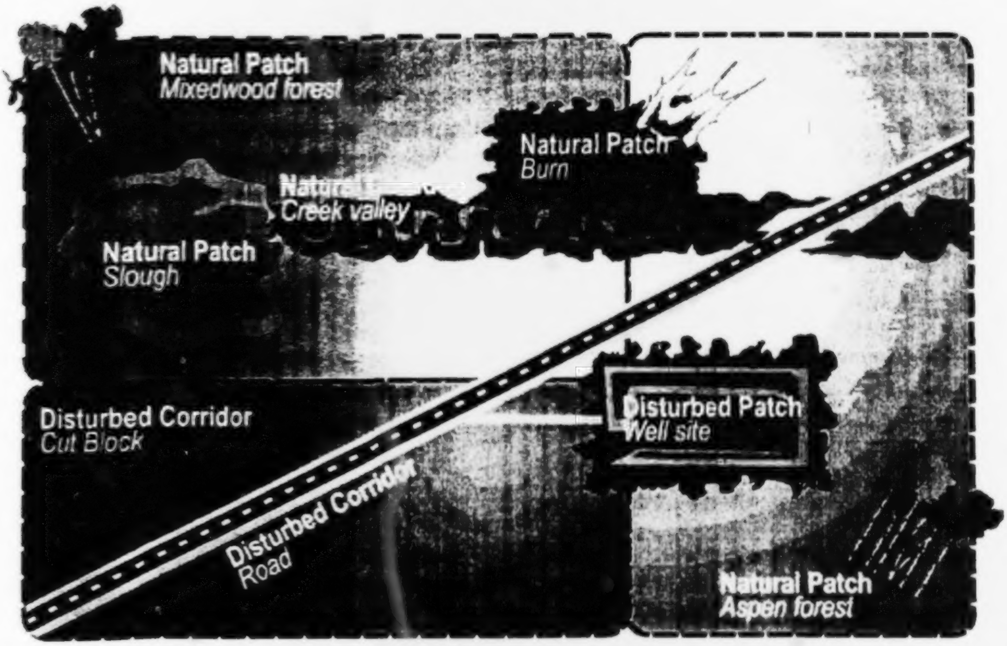

Figure 1. Elements of a forest landscape.

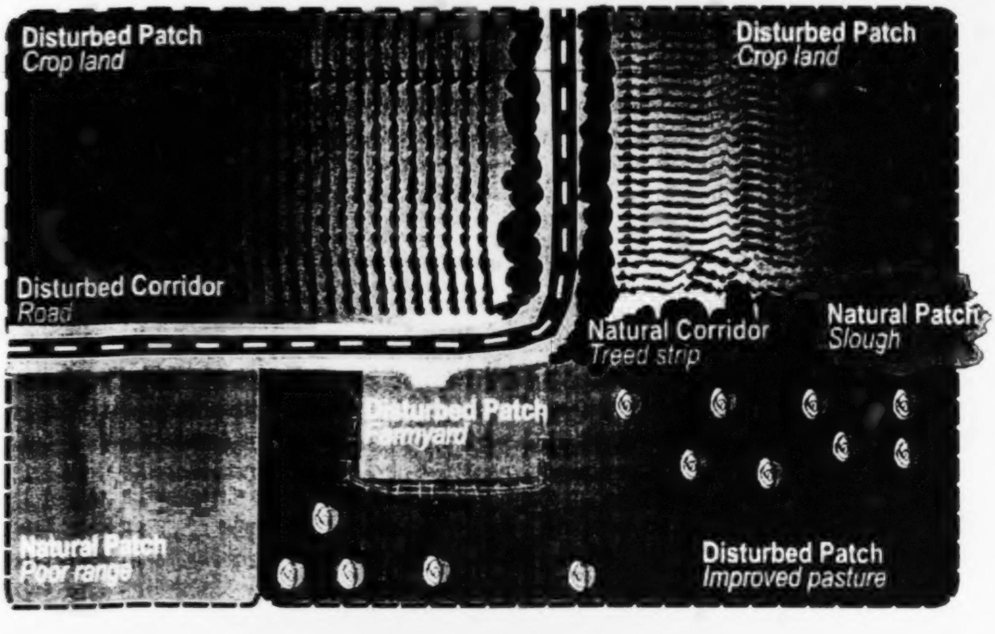

Figure 2. Elements of an agricultural landscape.

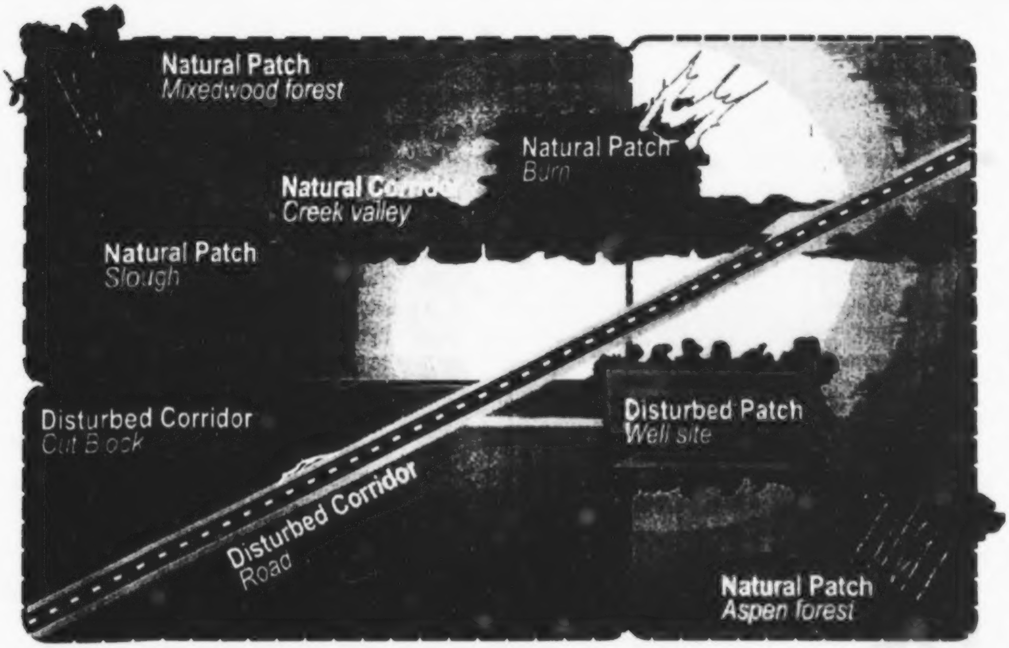

Figure 1. Elements of a forest landscape.

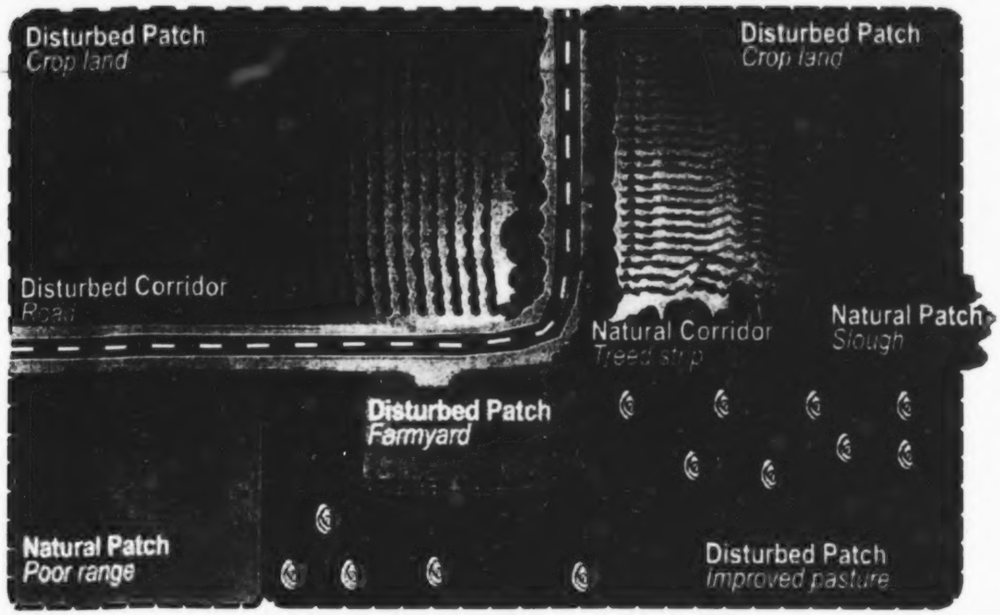

Figure 2. Elements of an agricultural landscape.

2.1.2 Aquatic Habitat

Landscape ecology can also be applied to aquatic systems. Watersheds are topographically defined areas within which surface water runoff drains to a lake or specific point on a stream. Watersheds are generally accepted to be an appropriate study unit because the quantity and quality of water and associated habitat at a specific point reflects the aggregate physical, chemical, and biotic factors upstream of this point (Omernik and Bailey 1997). Watersheds have provided the spatial boundaries for scientific study of the effects of natural and human factors on hydrology, water quality, and aquatic biota.

These factors display considerable variability over time and space and can be considered to occur along four dimensions. The longitudinal dimension integrates upstream-downstream linkages. Exchanges of matter and energy take place between waterbodies and the riparian/floodplain system along the lateral dimension. Interactions between waterbodies and groundwater occur along the vertical dimension. These pathways are integrated over time, the fourth dimension (Ward 1989).

Aquatic habitat can be divided into three main components: lentic, lotic, and riparian.

- **Lentic**, or standing water, habitat is found in wetlands, ponds, and lakes. The aquatic organisms found in a particular waterbody depend on its depth, size, substrate (bottom type), water quality, and the abundance and type of littoral (shallow nearshore) habitat, among other factors (Wetzel 1975).
- **Lotic**, or running water, habitat is found in creeks, streams, and rivers. Lotic systems normally consist of a pattern of tributaries joining one another and ultimately forming the 'mainstem' channel (Hynes 1970).
- **Riparian** areas include the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995a, BCF 1999).

2.2 NATURAL VARIABILITY

The concepts of natural range of variability and ecological resilience are important for cumulative effects assessment and management. An underlying assumption of ecosystem management is that using natural disturbance patterns to guide management actions is one of the best possible means of achieving ecological sustainability in the absence of information on alternatives (Frissell and Bayles 1996; Andison 1999, 2000). A number of predictive modelling techniques incorporating random (stochastic) events have been developed to estimate the range of natural variability (Salmo et al. 2001).

2.2.1 Habitat

2.2.1.1 Terrestrial

Environmental conditions, habitat, and populations display natural variability that result from long-term climatic trends, short-term weather fluctuations, natural succession, and random events. The **natural range of variability** is determined by these factors as well as physiographic and watershed characteristics. The frequency and magnitude of disturbance events affect the composition, productivity, and successional state of terrestrial and riparian vegetation and stream channel characteristics (Ward 1989; Regier and Meisner 1990). Thus, the distribution, pattern, abundance, and connections between habitat units change in both time and space.

The primary natural disturbances influencing terrestrial habitat in the boreal forest are fire, insect and disease outbreaks, floods, and beaver (*Castor canadensis*) dams. Fire and insect outbreaks are by far the most important, and natural range of variability is often related to fire cycle (e.g., BCF and BCE 1995a). Fire cycles in the boreal forest have changed at least three times in the past 300 years, probably due to climate changes. Small fires (< 4 ha) have been most common, but infrequent large fires account for most of the area burned on a cumulative basis. Because fire cycles have been shorter than the lifespan of the dominant trees, old growth forest generally comprises a small percentage of the landscape in the boreal forest (Andison 1999, 2000; Johnson et al. 2001).

Most of northeast British Columbia is included within Natural Disturbance Type 3 (NDT3): ecosystems with frequent stand-initiating events. Historically, these forests experienced frequent fires that ranged in size from a few hectares to hundreds of square kilometres. Average fire size was likely 300 ha in some parts of the Boreal White and Black Spruce biogeoclimatic zone (BWBS; *Picea glauca* and *P. mariana*), but went as high as 6,000 ha in areas where topographic features did not limit fire spread. There were also frequent outbreaks of defoliating insects. Riparian areas provided special habitat characteristics not found in upland areas (BCF and BCE 1995a,c).

The mean disturbance event interval in NDT3 is 100 years for BWBS deciduous stands, 125 years for BWBS coniferous stands and Sub-boreal Spruce (SBS) stands, and 150 years for Engelmann Spruce-Subalpine Fir (ESSF; *Picea engelmannii-Abies lasiocarpa*) stands. Old growth stands are considered to be >100 years for BWBS deciduous stands, and >140 years for BWBS coniferous stands, SBS stands, and ESSF stands (BCF and BCE 1995a, BCF and MELP 1999b).

2.2.1.2 Aquatic

Disturbance events such as fires and windstorms that dramatically shape terrestrial systems may have relatively subdued long-term effects in aquatic systems (Minshall et al. 1997). Aquatic ecosystems respond more significantly to floods, acceleration of erosion, and channel barriers that have rather subtle or spatially restricted effects on terrestrial systems (Frissell and Bayles 1996).

The frequency and magnitude of flood events affect the composition, productivity, and successional state of riparian vegetation as well as the connectedness, depth, and productivity of floodplain channels (Ward 1989; Regier and Meisner 1990). In the boreal forest, the spring peak flow that results from melting snow is the largest runoff event of the year in 9 years out of 10. In one year out of 10 or 15, the largest peak event of the year is produced by a summer rain event; these rain-caused peak flows are by far the largest events (Alke 1995). Extreme changes in the amount of precipitation may cause floods or droughts that cause heavy sedimentation, alter channel morphology, and restrict fish movements (Meehan 1991).

Beaver dams, forest fires, strong winds, and landslides, can alter water quality, channel morphology, mobilize coarse woody debris that provides cover for fish, and create barriers to movement (Meehan 1991; Young 1994; Magnan and St-Onge 2000). The location and persistence of natural barriers are particularly important for migratory species such as Arctic grayling (*Thymallus arcticus*) and bull trout (*Salvelinus confluentus*) undertake seasonal movements between overwintering, rearing, and spawning areas.

2.2.2 Populations

Ecological resilience refers to the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996). Although fish and wildlife species present in northeast British Columbia have adapted to natural disturbances, individual species differ in their inherent ability to absorb disturbance and still persist as viable populations.

At the regional scale, ecological resilience is enhanced among groups of small, extinction-prone local populations that are linked by the movement of individuals between them (Hanski and Gilpin 1991). These **metapopulations** increase persistence by spreading the risk of disturbance occurring at the local population and individual levels over time and space. Species that are spatially restricted to a single subpopulation or a few individuals have lower ecological resilience and are less likely to persist over time (Weaver et al. 1996).

At more local scales, **population**-level responses such as increased reproduction and survival (generally referred to as compensation); offset increased rates of juvenile and adult mortality and thereby minimizing population fluctuations over time. These **density-dependent** effects are related to population size. Dispersal (immigration and emigration) by juveniles and adults is the mechanism by which vanishing local populations are rescued from extirpation and connectivity of metapopulations is maintained through time. In addition, local populations may exhibit a variety of life forms that increase the overall resilience of the metapopulation (Frissell and Bayles 1996; Mayhood 2001).

Finally, behavioural flexibility allows **individuals** to respond to local changes in habitat availability and quality and meet their energetic and reproductive needs (Weaver et al. 1996). This behavioural flexibility also complicates assessments of species response to both natural and human disturbance and is particularly relevant to the discussion of disturbance included in Section 2.3.4.

Species that mature early, have high reproductive rates, and are able to exploit a wide variety of food sources have higher ecological resilience because they are more able to compensate for natural and human disturbance. Other factors that affect species resilience include annual and seasonal home range size, population density and distribution, life expectancy, dispersal rates, ability to habituate, size, and mode of locomotion (Weaver et al. 1996).

At any point in time, population abundance and distribution reflects habitat availability and quality, as well as biological factors such as immigration, emigration, and juvenile and adult mortality that are dictated by weather, predation rate, and life history patterns. Population variability appears to increase with the length of time over which it is monitored or calculated, and this is assumed to reflect the influence of long-term positive or negative trends in abundance (Pimm and Redfearn 1988). Except for species with generation times longer than about 6 years, the range of variability observed after 50 years is assumed to correspond to normal variability excluding trends and major natural catastrophes (Thomas 1990). Populations occupying marginal or sub-optimal habitat should be expected to experience higher year-to-year fluctuations in abundance (Boulinier et al. 1998).

Environmental conditions during the winter and spring may have dramatic effects on fish and wildlife populations in this region that are not related to population size (**density-independent**). Winter snow depth is critical for many resident wildlife populations. Snow depths greater than 40 cm for deer (*Odocoileus* spp.), 50 cm for elk (*Cervus elaphus*), and 65 cm for moose (*Alces alces*) may result in significant overwintering mortality (Nietfeld et al. 1985). Weather conditions during the spring birthing period also affect neonate survival. Overwintering habitat may limit fish populations (Cunjak 1996). Water temperatures, current velocity, and water levels during the spring spawning, incubation, or emergence period often regulate year-class strength (Hubert et al. 1985; Ford et al. 1995; Cattaneo et al. 2002).

Natural disturbances, like a serious spruce beetle (*Dendroctonus rufipennis*) infestation of a coniferous forest, will have a variety of effects on bird populations. Bird responses will vary depending on their ecological requirements (especially nesting affinities), their ability to exploit altered habitats, the specific forest components experiencing change, and the time elapsed since the disturbance event. For example, a bird species requiring coniferous habitat for nesting and foraging had much lower abundance in heavily beetle-impacted boreal spruce forests, while understory-nesting birds, as a group, had significantly higher abundance in the same areas (Matsuoka et al. 2001).

2.3 CUMULATIVE EFFECTS IN NORTHEAST BRITISH COLUMBIA

In northeast British Columbia, cumulative effects result from direct loss and alteration of habitat due to petroleum exploration and production, forest harvest, agriculture and cattle grazing, subsistence and recreational use, municipal, urban, and residential development, and other industrial activities. Indirect disturbance and wildlife harvest also occurs due to use of roads and trails by recreational and subsistence users (e.g., hunters, fishermen). Cumulative effects can be classified into four types:

1. Habitat alteration, loss, and fragmentation,
2. Barriers to movement,
3. Direct and indirect mortality, and
4. Disturbance.

These four types will be discussed in greater detail in the sections below.

2.3.1 Habitat Alteration and Loss

Terrestrial **habitat loss** occurs when human activities disturb the soil or remove vegetation and regrowth does not occur (e.g., construction of a highway, secondary road, or industrial facility). This reduces available habitat for all species as long as the feature persists. Aquatic habitat loss occurs when water is removed, chemistry is substantially altered, or bed and banks are substantially altered.

Temporary **habitat alteration** occurs until natural conditions are restored to disturbed areas and waterbodies. Long-term or permanent terrestrial habitat alteration occurs when different vegetation regrows on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production or reseeding a pipeline right-of-way with non-native agronomic species). Permanent aquatic habitat alteration occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Permanent habitat alteration can also result from the introduction of non-native or exotic species (Douglas et al. 1990) and changes in grazing patterns and intensity (Platts 1991). The spread of non-native plants is affected by their dispersal capacity and the quality of immediately adjacent habitat. Cattle and linear disturbance corridors such as roads and trails can facilitate the spread of these species (Fleischner 1994; van Dorp et al. 1997; Hobbs 2001).

2.3.1.1 Habitat Fragmentation

Both dramatic and minor changes in habitat can benefit some species and hinder others. **Fragmentation** of the landscape occurs as continuity of the original matrix habitat is disrupted (Collinge 1996). Throughout history, fragmentation has naturally occurred through disturbances like glaciation, floods, and fires. In recent times, fragmentation has also occurred through conversion of lands for human use (e.g., harvesting and converting forest; tilling native prairie for use as crop-land).

Three general effects result from habitat fragmentation (Figure 3):

1. original habitat is lost,
2. remaining habitat patches decrease in size, and

3. patches become increasingly isolated from one another.

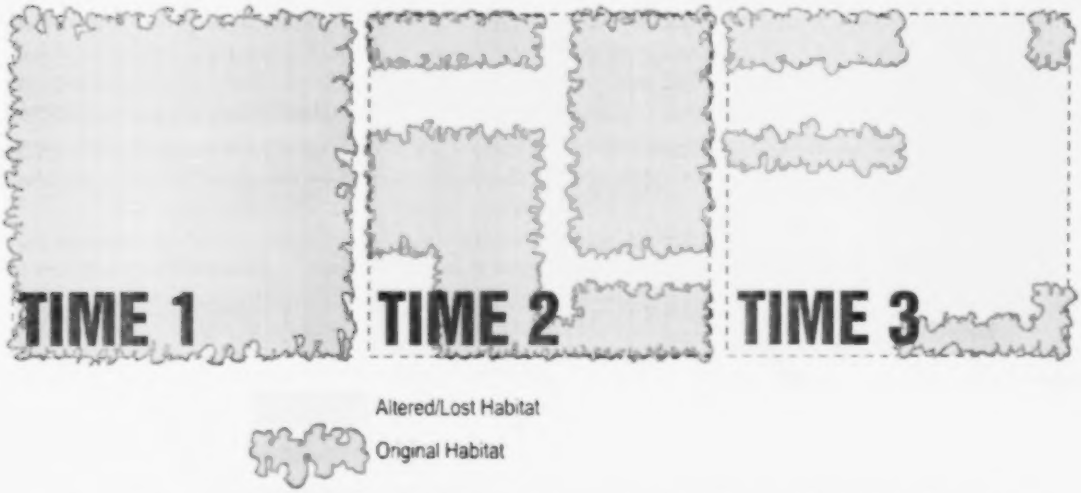

Figure 3. Representation of the habitat fragmentation process (adapted from Collinge 1996).

As original landscapes and aquatic habitat units become smaller and isolated, ecosystem function can be disrupted. With fragmentation, patches become more vulnerable to natural and human disturbances such as windstorms, fires, flooding, and non-native species invasion. This may affect pollination, seed dispersal, predation, and nutrient cycling (Lord and Norton 1990), exclude certain species, or increase their extinction probability over time (Andrén 1994; Collinge 1996).

As described further in Section 5.4, there are certain critical thresholds in the process of habitat fragmentation where rapid changes in the size and isolation of patches occur. A similar process can occur at the regional scale as original landscapes become smaller and isolated (Andrén 1994; With and Crist 1995; Mönkkönen and Reunanen 1999).

2.3.1.2 'Edge' Effects

Habitat alteration may occur indirectly through **'edge' effects** at the boundaries where a new patch or corridor joins the matrix. As expanses of continuous vegetation are fragmented, edges between the patches and surrounding habitat increase in length. Edges are particularly noticeable in forested landscapes, because of their dominant vertical structure.

Moisture, light, temperature, and wind regimes may change significantly at the fragment edge, and effects may extend into the patch for tens of metres. Edge orientation will affect the amount of environmental change; windward and/or south-facing edges will be warmer, drier and wider than leeward or north-facing edges. With the altered environmental conditions, the structure and composition of edge plant communities generally differ from those in interior (hereafter referred to as core) habitat. Other observed 'edge' effects include increased predation, mortality, competition, and brood parasitism; changes in vegetation diversity and structure; and changes in species composition and abundance (van der Zande et al. 1980; Wilcove et al. 1986; Laurance and Yensen 1991; Collinge 1996; Reed et al. 1996a; ESGBP 1998).

Edge effects are more pronounced in small or thin patches, since the ratio of edge to interior increases geometrically with decreasing patch size (Temple and Cary 1988; Collinge 1996; Culling and Anderson 2001). In very fragmented forests, virtually all remaining habitat may be so close to an edge that no functional core habitat remains (Temple and Cary 1988). For instance, if edge effects are assumed to extend 50 m from a patch edge, then a 1-ha square patch will contain no core habitat whatsoever while a 100-ha square patch will contain 81% core habitat (Figure 4; Collinge 1996). In contrast, a narrow 100 ha rectangular patch will contain only 69% core (Figure 5; Collinge 1996).

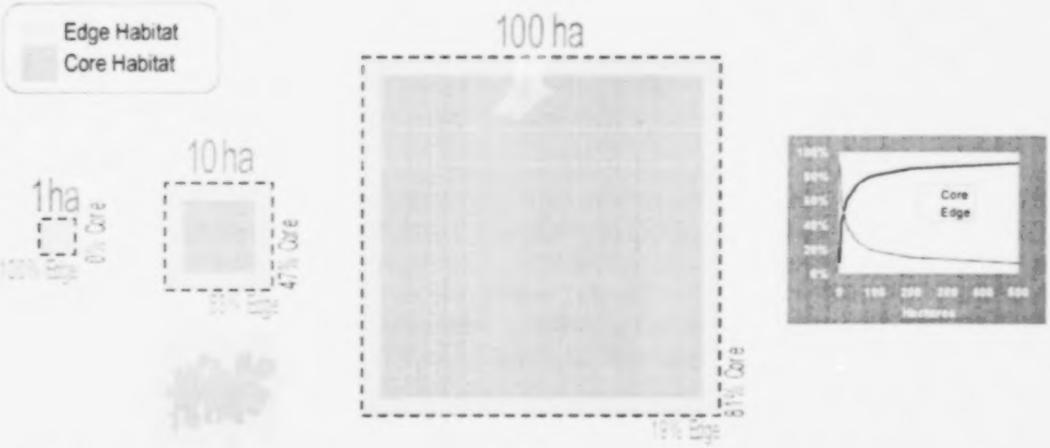

Figure 4. Relationship between patch size and edge area assuming 50 m edge width (adapted from Collinge 1996).

Roads create substantially more edge than clearings of equivalent area, due to patch geometry (Figure 5). In a foothills area, roads created 1.5 to 2 times more edge habitat than clearcuts. Taken together, roads and clearcuts influenced 2.5 to 3.5 times the land area directly disturbed by these uses (Reed et al. 1996). Roads will impact immediate and adjacent habitat quite differently than clearcuts; they can be expected to alter soil density, surface temperature, soil water content, light, dust, surface-water flow, pattern of run-off, and sedimentation (Trombulak and Frissell 2000).

The biological significance of edge effects differs between organisms and may need to be quantified by identifying the amount of habitat usable by a particular species (Andrén 1994; Fahrig 1997; Pasitschniak-Arts and Messier 1998; Mönkkönen and Reunanen 1999).

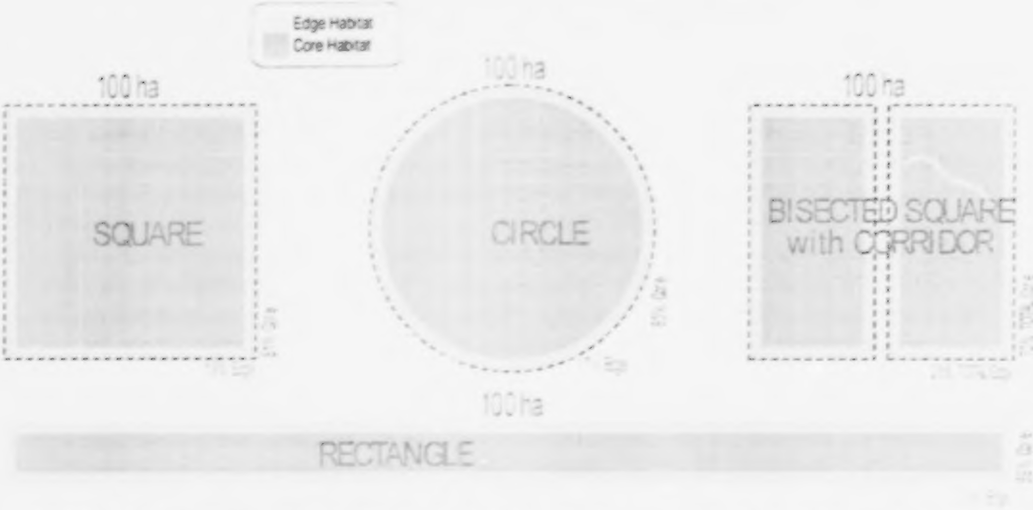

Figure 5. Relationship between patch geometry and edge area assuming 50 m edge width (adapted from Collinge 1996).

Overall, at any given scale, fragmentation is more likely to affect habitat specialists than habitat generalists (Lord and Norton 1990; With and Crist 1995; Collinge 1996; Kolozsvary and Swihart 1999), and core-adapted species than edge-adapted species (Figure 6). Edge effects are discussed further in Section 3.4.1.3.

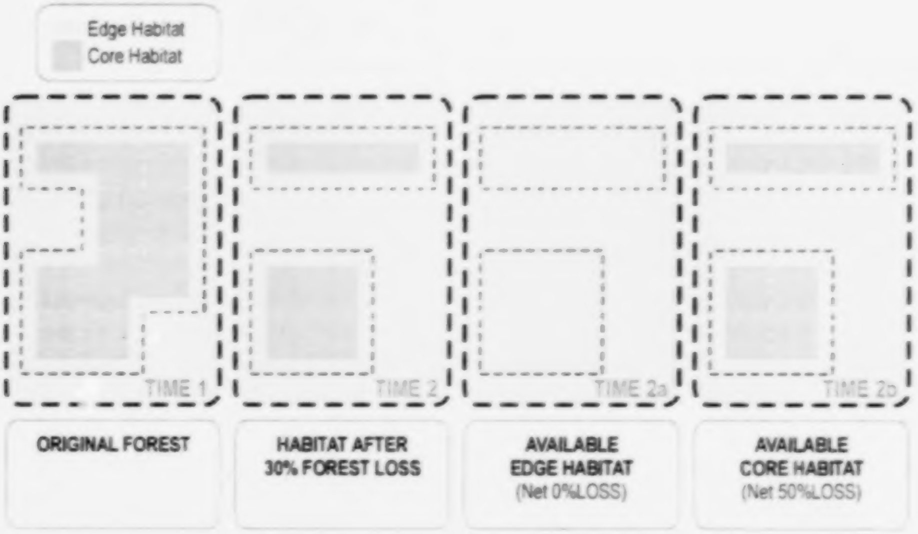
Edge Habitat
Core Habitat
TIME 1
TIME 2
TIME 2a
TIME 2b
ORIGINAL FOREST
HABITAT AFTER 30% FOREST LOSS
AVAILABLE EDGE HABITAT (Net 0%LOSS)
AVAILABLE CORE HABITAT (Net 50%LOSS)

Figure 6. Contrast between habitat loss for edge versus core species (adapted from Fahrig 1997).

2.3.1.3 Synergistic Effects: Livestock Grazing

Cumulative effects of habitat alteration and loss result from the total changes associated with existing, proposed, and likely future activities. For example, the combination of livestock grazing and human development appears to create a synergistic cumulative effect – one that is greater than that expected by adding the individual effects.

Forest ecosystems have evolved with grazing and browsing by native herbivores such as moose, elk, and deer. Under natural conditions, grazing pressure and intensity was variable and within the carrying capacity of the range. If forage production decreased, herbivores either moved to more favourable range or perished, bringing populations into balance with habitat capacity. Native vegetation became adapted to intermittent cropping by variable numbers of animals followed by years of rest.

In contrast, grazing and browsing by domestic livestock, along with associated agricultural practices, have decreased the density of native plant species and the diversity of native plant communities throughout western North America. A key difference is that livestock are confined within barriers, continually grazing the same range, sometimes at a rate higher than the area's carrying capacity. Restricted movement and higher stocking rates result in trampling and compaction of the soil, encouraging a vegetation change to shallow-rooted annual species or taprooted perennials that can grow in areas with lowered water tables (Epp and Townley-Smith 1980; Platts 1991; Fleischner 1994).

Livestock are attracted to riparian areas bordering waterbodies and these areas appear to have suffered greater habitat loss and alteration than upland areas in western North America (Platts 1991; Fleischner 1994). In forested areas, they may also create edge effects by attracting cowbirds (*Molothrus ater*), a nest parasite that reduces the nesting success of forest songbirds.

Non-working areas of wellsites are normally revegetated following construction in pasture. However, cattle appear to be attracted to these structures and sites, leading to nearly constant trampling of these areas (Epp and Townley-Smith 1980; ERIN 2000), and increasing the spread of weeds and non-native species. The resulting bare areas exceed those that would result from either petroleum development or cattle grazing alone. Grazing can increase nesting habitat quality for some non-game upland bird species (e.g., shorebirds) while others have lower nesting frequency in active grazing areas (e.g., sharp tailed grouse [*Tympanuchus phasianellus*]; Kantrud and Higgins 1992).

Thus, the net cumulative effect on habitat reflects habitat alteration and loss from all sources, as well as other types of effects such as barriers to movement and increased mortality.

2.3.2 Barriers to Movement

Animals may be reluctant or unable to cross corridors, although the actual effect depends on the species, the width of the corridor, the corridor characteristics, the surrounding habitat, and the frequency and volume of human use. In general, the likelihood and magnitude of barrier effects increases as corridor width increases, the corridor becomes more dissimilar from surrounding habitat, and vehicular and human use of the corridor increases.

A **barrier** is present when no movement occurs across a corridor and the habitat on either side of the corridor becomes fragmented at the individual animal or local scale. An example is an improperly constructed road culvert that completely blocks fish movement (Harper and Quigley 2000).

If some movement occurs but the rate of movement is less than through intact habitat, then the corridor is considered a **filter** or **porous barrier** (Jalkotzy et al. 1998). The busy Alaska Highway would be considered a filter for large mobile wildlife such as deer but might represent a barrier for small ground-dwelling insect species. In the forest landscape, most trails and roads are assumed to be filters for key wildlife species since they are comparatively narrow, low activity features that do not dramatically differ from the surrounding habitat.

2.3.3 Direct and Indirect Mortality

Activities associated with corridors may cause direct mortality, or increase the risk of mortality. This includes wildlife-vehicle collisions, powerline strikes or electrocutions, and fish mortality due to instream blasting or water withdrawal. Increased mortality risk is associated with hunter or predator use of corridors and facilities, and results from increased harvest facilitated by access. Both direct and indirect mortality affect the numbers of animals present in an area (Jalkotzy et al. 1998).

Hunting, fishing, and trapping can alter behaviour, population structure, and distribution patterns of fish and wildlife populations. In some cases, harvest may be partially if not completely additive with natural mortality (density-independent); immigration from unexploited areas may be necessary to sustain harvested populations (Knight and Cole 1995a; Kitchen et al. 1999).

Cumulative effects frequently occur because access corridors created for an individual project increase the level of human activity from all users. This can lead to increased harvest effort and success, increased vehicle mortality, and increased animal removal/ mortality for wildlife management (e.g., problem bears). These indirect mortality effects are difficult to manage (Mychasiw and Hoefs 1988; Trombulak and Frissell 2000).

2.3.4 Disturbance

Man-made facilities and corridors and the activities associated with them can directly and indirectly affect animals. The type and magnitude of impacts varies with the type of human activity. Consumptive activities such as hunting and fishing have a different impact than non-consumptive activities such as nature viewing. Motorized and non-motorized activities also have different effects (Knight and Cole 1995b). In most cases, the mere presence of a structure or right-of-way in grassland areas does not appear to disturb wildlife. Responses in forested areas are less clear and vary by species, season, and disturbance width, size, and geometry, among other factors.

Most published studies have focussed on short-term responses to human activity (Knight and Cole 1995a; Hill et al. 1997). In general, impacts are inversely related to the level and predictability of human disturbance. Continuous, frequent or unpredictable high intensity activities (e.g., motorized snow machines, powerboats, gun shots) cause greater response than low intensity or infrequent activities (e.g., generator motor noise). Human activity usually generates greater response than vehicle or equipment activity (e.g., Perry and Overly 1977; Holton 1982; Murphy and Curatolo 1987; Henson and Grant 1991; Hockin et al. 1992; Andersen et al. 1996; Hill et al. 1997; Webster 1997; Kitchen et al. 1999). Response is also affected by the type of activity, the timing and location of the activity, the age and sex of individuals, as well as the group size (Knight and Cole 1995b).

Animals may display a waning response to repeated or predictable disturbance that is perceived to be nonthreatening. This 'habituation' is most likely to occur in protected areas, or areas with consistently high levels of human activity (Knight and Temple 1995).

Disturbance may affect animals at the individual, population, and community level. Individual responses include *physiological changes* (e.g., increased heart rate), *behavioural changes* (e.g., reduced use of disturbed areas), and *ecological changes* (e.g., altered reproductive success). These individual responses may combine to produce effects at the population level such as altered abundance, spatial distribution, mortality rate, and reproductive rate. Differences in the responses of individual species can lead to community level changes in relative abundance, competition, or other species interactions (Karr and Freemark 1985; Knight and Cole 1995a).

2.3.4.1 Individual and Behavioural Response

A single disturbance event usually has only a short-term impact on an individual animal. For example, a deer will run over a ridge to get out of sight of a person walking down a trail, but may choose to return and resume its earlier activities once the person passes. This response may carry a cost in terms of energy expenditure and lost feeding. It will vary between animals, though; hunted populations typically exhibit stronger disturbance reactions to people along roads than do wildlife in protected areas.

Repeated human activity can cause cumulative impacts when areas adjacent to human-disturbed patches and corridors are used less than nearby areas with identical habitat. This loss of '*habitat effectiveness*' can accumulate over time and lead to progressive declines in species diversity and abundance (van der Zande et al. 1980; Riffell et al. 1996; Richardson and Miller 1997; Rodgers and Smith 1997; Gutzwiller et al. 1998; Jalkotzy et al. 1998).

Figure 7 depicts road-habitat effectiveness models developed for a hunted elk population; habitat effectiveness is inversely related to road density. This figure also demonstrates the effect of disturbance intensity on habitat effectiveness. Infrequently used access features like 'Primitive Roads' affect elk habitat use considerably less than more regularly used 'Primary Roads' and 'Secondary Roads' with moderate traffic volumes (Thomas et al. 1979; Lyon 1984; Thomas et al. 1988).

It is important to note that behavioural responses to disturbance and reduced reproductive success may not translate into population-level effects such as reduced animal numbers described below. This is particularly true for species with high reproductive rates and those that habituate to repeated disturbance (e.g., Geist 1978; Bergerud et al. 1984; Hockin et al. 1992).

2.3.4.2 Population or Ecological Response

Repeated disturbance can affect habitat use, reproduction, and survival; it can ultimately change population or community dynamics (Geist 1978; Yarmoloy et al. 1988). Responses vary considerably between and within species, but documented examples for birds include changes in feeding patterns, compromised nest defence, and reduced hatching and fledging success (Safina and Burger 1983 *in* Riffell et al. 1996, Tuite et al. 1984, Keller 1989 *in* Riffell et al. 1996; Skagen et al. 1991; Holmes et al. 1993, Riffell et al. 1996; several authors cited in Richardson and Miller 1997; Rodgers and Smith 1997; Gutzwiller et al. 1998). This is a potential concern for rare species with low abundances where displacement could affect their continued presence in an area (Hockin et al. 1992; Riffell et al. 1996).

While the importance of disturbance on animals is acknowledged, the understanding of population-level response is incomplete because populations respond simultaneously to both natural and human-caused influences (Hill et al. 1997).

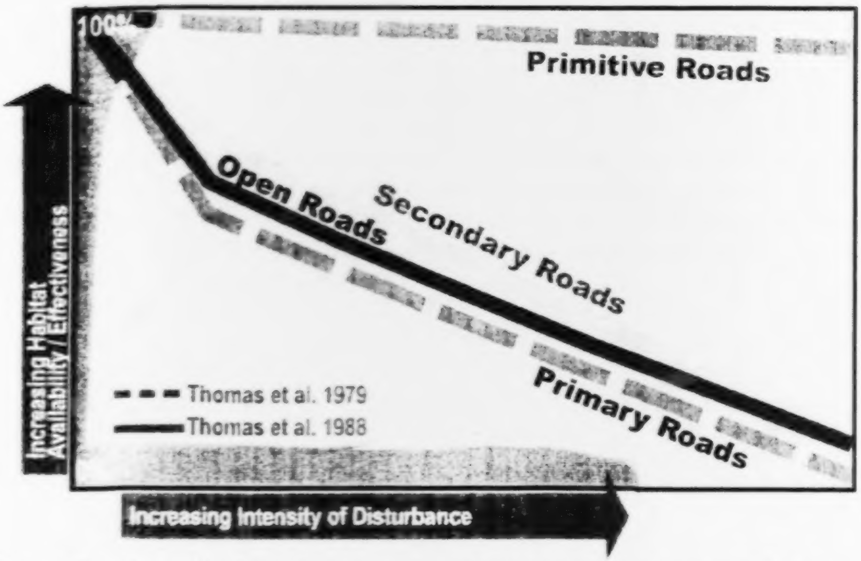

Figure 7. Impact of roads on predicted habitat effectiveness for elk.

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Repeated disturbance can affect habitat use, reproduction, and survival; it can ultimately change population or community dynamics (Geist 1978; Yarmoloy et al. 1988). Responses vary considerably between and within species, but documented examples for birds include changes in feeding patterns, compromised nest defence, and reduced hatching and fledging success (Safina and Burger 1983 *in* Riffell et al. 1996, Tuite et al. 1984, Keller 1989 *in* Riffell et al. 1996; Skagen et al. 1991; Holmes et al. 1993, Riffell et al. 1996; several authors cited in Richardson and Miller 1997; Rodgers and Smith 1997; Gutzwiller et al. 1998). This is a potential concern for rare species with low abundances where displacement could affect their continued presence in an area (Hockin et al. 1992; Riffell et al. 1996).

While the importance of disturbance on animals is acknowledged, the understanding of population-level response is incomplete because populations respond simultaneously to both natural and human-caused influences (Hill et al. 1997).

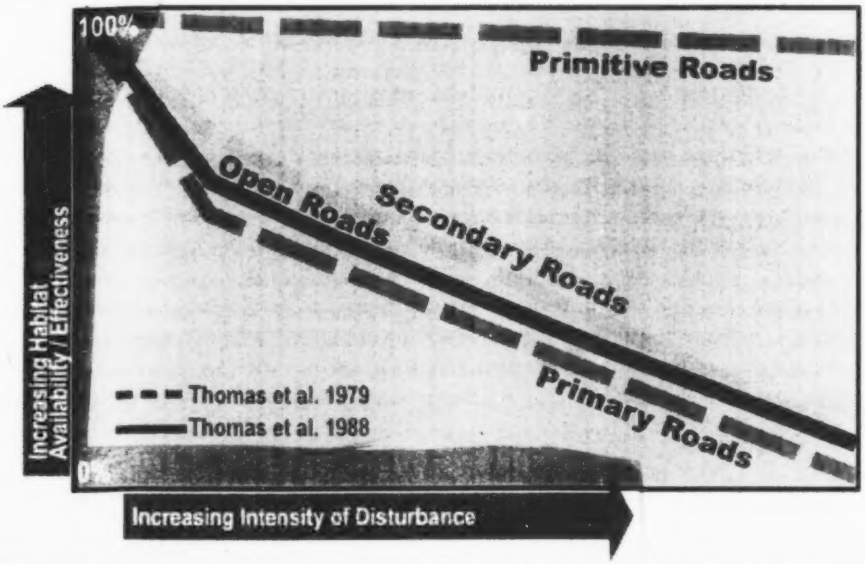

Figure 7. Impact of roads on predicted habitat effectiveness for elk.

3. MANAGEMENT THRESHOLDS

A **threshold** is an objective, science-based standard used to evaluate the acceptability of project-specific and cumulative effects (Ziemer 1994); acceptability can be defined from an ecological or social perspective. Thresholds should be based on measurable, attainable, and applicable attributes of ecosystems, communities, assemblages, or species (Merigliano et al. 1997; Hughes et al. 1998; Axys 2001a).

The threshold concept presumes that ecological or social capacity exists to appropriately accommodate human disturbance, that we are capable of identifying this capacity, and that we will implement activities that will not violate it. It also assumes that ecosystems and watersheds possess inherent resilience that allows recovery from past and continued human disturbance (Frissell and Bayles 1996).

A perceived regulatory advantage of thresholds is that they allow development activities to proceed without detailed review until the defined threshold is reached. Thus, if the incremental effects of a proposed activity do not cause threshold exceedance, then the effects are concluded to be insignificant and the proposal proceeds. However, once the threshold is reached, extra review or regulation is necessary (Ziemer 1994; Axys 2001a).

Thresholds may be based on outcomes (desired habitat or social conditions) or inputs (activity intensity). Outcome-based thresholds are preferred, since outcomes can be influenced by more than one input, and it is the outcome that is important from a management perspective. Nevertheless, thresholds based on acceptable inputs are required when desired outcomes cannot be practically defined (Merigliano et al. 1997). Examples of thresholds identified by Merigliano et al. (1997), Axys (2001a), and others are provided in Table 1.

Table 1. Examples of input-and output-based thresholds.

Output-Based Thresholds	Input-Based Thresholds
• Minimum amount of suitable habitat within a specified geographic area or watershed (e.g., greater than 60% moderate and high suitability habitat).	• Maximum human disturbance rate (e.g., maximum allowable backcountry trail use in persons/month).
• Number of animals in a specific geographic area or waterbody (e.g., 1,800 moose in a specified wildlife Management Unit).	• Maximum level of land use activity or development within a specified geographic area or watershed (e.g., cleared area, length of access, access density).
• Maximum body burden (e.g., tissue mercury content).	• Maximum pollutant ambient concentration or deposition rate.
• Non-native species presence (e.g., designated exotic weeds present on no more than 2% of area).	• Lowest pollutant concentration at which an adverse health or ecological effect is observed.

Four main types of indicators and thresholds can be identified: Physical and Chemical, Ecological, Land Use, and Social. The review provided here emphasizes ecological and land use indicators and thresholds; social indicators are not discussed. Physical and chemical thresholds are well established and widely applied, and they are briefly discussed as background to the discussion of indicators and thresholds of most direct relevance to fish and wildlife management. Additional information specific to each of these types is discussed as follows:

- Physical and Chemical Indicators and Thresholds (Section 3.2)
- Ecological Indicators and Thresholds (Section 4)
- Land Use Indicators and Thresholds (Section 5)

3.1 PHYSICAL/CHEMICAL INDICATORS AND THRESHOLDS

The best examples of science-based thresholds are air and water quality criteria developed by the provincial and federal governments. These are based on observed or modelled dose-response relationships; an example of which is shown in Figure 8.

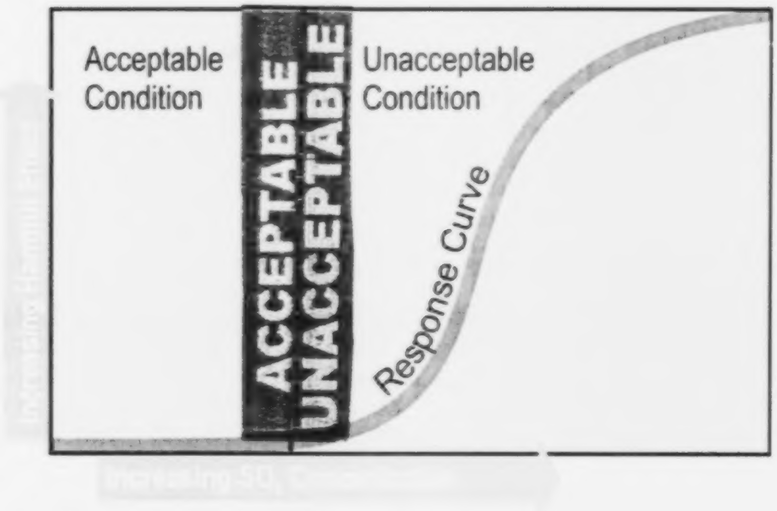

Figure 8. Theoretical dose-response curve showing an effect threshold.

In this example, the air quality threshold represents the concentration that causes detectable effects on a sensitive receptor (e.g., reduced growth of lichen). Identification of specific thresholds may be difficult because effects differ with the averaging period used, type of exposure (e.g., chemical form, dose), the ecological setting, and the life stage of a species. With this inherent uncertainty, regulators may build in a safety margin by choosing a threshold below the lowest detected effect concentration (Bull 1991).

In northeast British Columbia, federal and provincial air and water quality thresholds are routinely applied to evaluate proposed activities. These thresholds are designed to provide long-term protection to the environment (CCME 1996; MELP 2001).

3.2 TIERED THRESHOLDS

Tiered thresholds were originally developed to manage deposition of acidic air pollutants (Bull 1991, 1992). This approach provides an integrated framework that uses two or more quantitative thresholds to identify appropriate management and regulatory responses.

Figure 9 illustrates the tiered threshold model defined by the Clean Air Strategic Alliance (CASA; AENV and CASA 1999) for management of potential acidification input. This model identifies three receptor-based management tiers: **Critical**, **Target**, and **Cautionary Thresholds**.

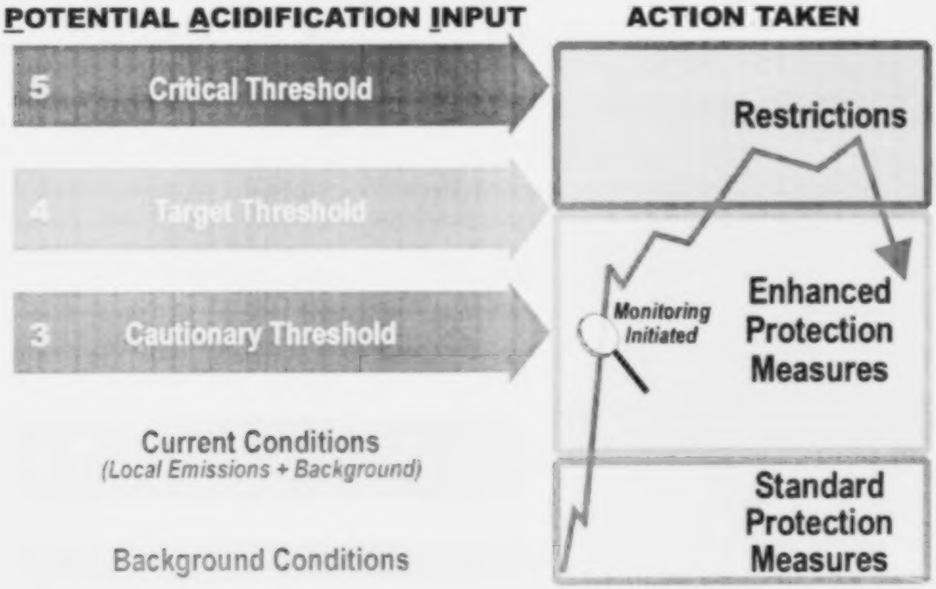

Figure 9. Application of tiered thresholds to management actions.

3.2.1 Critical Thresholds

A critical threshold is the continuous maximum amount of stress that an ecosystem or species can support without sustaining long-term harm (Bull 1992). To establish a critical threshold, an acceptable magnitude of change or level of protection must be defined. This definition should account for societal values on environmental quality and natural resource protection, which is difficult since there are many viewpoints on what constitutes an unacceptable 'adverse' effect. Once the acceptable protection level is defined, a science-based threshold is calculated from the best available information. This calculation is based on known cause and effect relationships like that depicted in Figure 8 (Bull 1991, 1992).

Acceptable change has been defined in a variety of ways. For example, the critical threshold may be based on predicted risk of population extinction (Lande 1987), predicted probability of population survival (Lamberson et al. 1992), or the probability and severity of an undesirable effect (Francis and Shotton 1997). CASA defined threshold loads from 'levels of protection', where a 100% level of protection meant protection for all ecosystems, while a 90% level of protection meant that 10% of ecosystems or species might experience stress above their critical load (AENV and CASA 1999). CASA defined Critical Thresholds as providing a 95% level of protection for sensitive, moderately sensitive, and low sensitivity soils.

When the Critical Threshold load is reached or approached, restrictive management practices are formally adopted. These can include pre-defined protection and recovery measures mandated through the review and approvals process. Examples include implementation of economic instruments that discourage emissions use, retrofitting of 'Best Available Technology', and use of predefined recovery responses like activity restrictions (AENV and CASA 1999).

3.2.2 Target Thresholds

A Target Threshold reflects a politically defined goal for the amount of stress on a system. It incorporates economic, social, and technological considerations; it should ideally be below the critical threshold to provide a margin of safety. A Target Threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

The Target Threshold may reflect a precautionary management philosophy or uncertainty associated with scientific predictions of the Critical Threshold. In Alberta, CASA defined the target acid deposition threshold loads at approximately 90% of the critical load (AENV and CASA 1999; Figure 9).

When this threshold is reached, enhanced management practices are formally adopted. These can include expanded environmental monitoring and applied research, voluntary use of 'Best Available Demonstrated Technology', and implementation of enhanced protection or recovery methods like 'No Net Habitat Loss' or restrictive harvest regulations (AENV and CASA 1999). Where existing disturbance levels exceed the critical threshold, the target threshold may be set at or above the critical threshold load, or a series of diminishing target threshold loads may be applied over time to progressively reduce stress to levels below the critical threshold (AENV and CASA 1999).

3.2.3 Cautionary Thresholds

A Cautionary Threshold is established to indicate when additional or more intensive monitoring is required. This concept was established by CASA (AENV and CASA 1999) to ensure that sufficient local data existed to confirm scientific predictions of both target and critical thresholds.

When this threshold is reached, issue-specific monitoring is initiated to document environmental conditions or responses. No other management or mitigation actions are required, but activities must comply with established regulatory guidelines and best industry management practices. Routine environmental and activity monitoring is also conducted to confirm that best management practices are being applied (AENV and CASA 1999).

Where there is not enough information to determine how much stress a system can sustain, a decision can be made to define an interim threshold between the cautionary and target thresholds. Final thresholds would be established only after further monitoring, research, and stakeholder consultation.

4. ECOLOGICAL INDICATORS AND THRESHOLDS

Unlike chemical criteria, ecological thresholds are not well established for management of fish and wildlife populations, habitat, and biodiversity. There is relatively little published research detailing their practical derivation and implementation.

Ecological indicators take several forms:

- **Habitat Conditions**: the predicted availability or quality of habitat for selected animal species or guilds based on mapped characteristics (Section 4.1,
- **Species, Communities, or Guilds**: the presence, relative abundance, or perceived 'health' of a single plant or animal or defined group of plants or animals. Generally selected based on: economic, social, or ecological importance; sensitivity to change; or special conservation status (Section 4.2),
- **Biodiversity**: the number of species, habitat units, or ecosystems present in a defined area (Section 4.3), and
- **Risk-based:** the predicted probability of species or population loss over a specified time period (Section 4.4).

4.1 HABITAT INDICATORS AND THRESHOLDS

Studies in both temperate and tropical areas have shown a positive relationship between the number of species and the area of contiguous suitable habitat (e.g., Forman and Godron 1986; Seagle 1986; Wilcove et al. 1986; Flather and Sauer 1996). Thresholds based on protection of habitat are often the most practical tool for managing cumulative effects on fish and wildlife species (Axys 2001a).

Figure 10 provides a theoretical example of how habitat-based ecological thresholds can be developed and applied using the road density-habitat effectiveness response provided in Figure 7. The green line displays the observed or predicted effect on habitat availability or effectiveness as disturbance intensity increases. No single point represents a transition from an acceptable to unacceptable state. Thus, biological thresholds are most reasonably represented as a range to better reflect natural variability in environmental conditions and population parameters (Axys 2001a). In this example, 30% habitat availability/effectiveness defines the transition point from acceptable to unacceptable habitat condition. This range may be established arbitrarily or based on a calculated degree of risk.

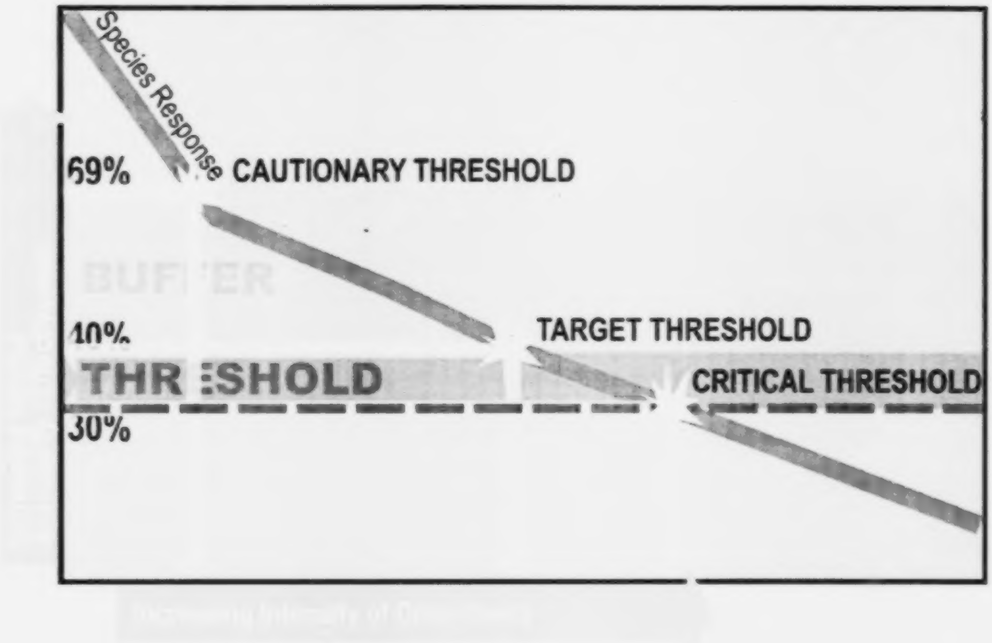

Figure 10. Ecological response curve and tiered habitat thresholds.

4.1.1 Habitat Availability

Habitat availability reflects an area's predicted wildlife capability or suitability by vegetation or ecological unit. These values estimate the area's ability to support and maintain individuals of an identified species (but see Van Horne 1983). Consideration of habitat availability allows terrestrial vegetation or ecological units and associated values (e.g., wildlife suitability, rare plant potential) to be quantified and compared with proposed habitat modification or loss at a variety of scales. Habitat suitability models frequently consider specific season and life requisites (Salmo et al. 2001).

Habitat thresholds are generally outcome-based. An outcome-based target threshold may be established at points where rapid changes in the size and isolation of habitat patches occur (e.g., change at 69% habitat indicator in Figure 10). Generalized habitat availability thresholds (e.g., >40% habitat availability) have been applied for landscape-level cumulative effects evaluations. Species-specific evaluations normally also consider the quality of available habitat (Table 2).

When more than 10% to 30% functional habitat remains in a region, species are affected by habitat loss, but strong habitat fragmentation effects are not common (Andrén 1994; Fahrig 1997). In a North America wide study of four species of breeding tanagers, Rosenberg et al. (1999) found that tanagers (as well as nest predators and parasites) exhibited the strongest negative response to fragmentation in areas of their range that were the most fragmented. Responses to fragmentation were significant but less severe in less fragmented areas (reviewed by Andrén 1994; Rosenberg et al. 1999). In a boreal landscape with only 11% of the forest harvested, habitat configuration explained significant variation in species presence/absence data for only 20% of bird species examined (Hannon 2000).

Table 2. Habitat availability guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Habitat Availability	- >10% to 30% of landscape in suitable habitat for birds and mammals (Andrén 1994).	- Threshold based on review of published studies and theoretical modelling.
	- >40% of landscape in suitable habitat for habitat specialists (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995).	- Theoretical threshold based on modelling.
	- >20% to 35% of landscape in suitable habitat for habitat generalists (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995).	- Theoretical threshold based on modelling.
	- 15% to 30% of forest in habitat conservation areas (Lamberson et al. 1994).	- Design for spotted owl reserves.
	- Landscape with 40% forest cover and 60% forage areas optimum for elk and deer (Thomas et al. 1979).	- Based on studies in Oregon.
	- >50% to 75% forest cover in areas greater than 9 to 10 km^2 (Hargis et al. 1999; Potvin et al. 2000).	- Recommendation to protect marten in eastern forests.
	- <10% of each Forest Operating Unit should be affected by logging (Horejsi 1996).	- Recommendation to protect grizzly bear in Yukon Territory.
	- <20% of watershed cleared within 10 years (McGurk and Fong 1995).	- Detectable changes in streamflow occur above this threshold.
	- 5% reduction in total forest area did not cause a detectable effect on relative abundance of forest interior songbirds, considered as a group; >10% reduction did (Rich et al. 1994).	- Based on studies in eastern forest.

4.1.2 Habitat Effectiveness

Some animals respond to human activities by modifying their behaviour and avoiding the affected area (Trombulak and Frissell 2000; Hamilton and Wilson 2001). **Habitat effectiveness** is an indicator of the value and amount of habitat available to an animal after accounting for the disturbance created by human infrastructure and activities. This indicator is calculated by species.

Calculation of habitat effectiveness is a three-step process (Axys 2001a; Salmo et al. 2001):

1. Habitat suitability models rate the quality of mapped ecological units for each species assuming *no human use*,
2. Human infrastructure and associated activities are stratified into groups with similar disturbance potentials. Each disturbance source is assigned a *zone of influence* (ZOI) that identifies the distance to which the species is affected by the activity. *Disturbance coefficients* (DCs) are assigned to each activity type, based on the degree to which the ZOI remains effectively useable by the species. DCs are determined from available literature or expert opinion; they range in value from 0 (i.e., no disturbance and no effect on the species) to 1 (i.e., high disturbance and probable exclusion of the species), and
3. An overlay of human use features and associated ZOI is integrated with the habitat suitability map, then the amount of effective habitat remaining is quantified for each analysis area (e.g., bear Wildlife Habitat Unit).

Table 3 presents some examples of established habitat effectiveness thresholds; most of these are outcome-based.

Table 3. Habitat effectiveness guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Habitat Effectiveness	▪ No net loss of habitat effectiveness for grizzly bear (BCF and MELP 1999a).	▪ Recommended British Columbia threshold.
	▪ >80% of all Bear Management Units with > 80% or greater habitat effectiveness for grizzly bear (Parks Canada 1997).	▪ Threshold adopted by Banff National Park.
	▪ >80% habitat effectiveness for elk (Servheen 1993).	▪ Grizzly bear management standard for Montana National Forest; based on Lyon (1979) elk-road model.
	▪ >80% habitat effectiveness for grizzly bear (Horejsi 1996).	▪ Recommendation calculated based on road density, assuming that 1 km/km^2 equates to 80% habitat effectiveness.

4.1.3 Edge

Natural and human-created edges of habitat patches differ ecologically from interior habitat, since edges have altered microclimate, changes in habitat type and quality, altered predation, parasitism and competition patterns, and changes in species composition and abundance (Taylor 1977; Wilcove et al. 1986; Laurance and Yensen 1991; Reed et al. 1996a; ESGBP 1998). Edge indices generally quantify the area where habitat quality is, or may be, affected by natural and man-made fragmentation.

Edge indicators take two forms:

1. Mathematical metrics that relate the total length of edge to the area of interior (km per ha) or a predefined analysis area (km per km^2), and
2. Estimates of the area affected by 'edge' effects (i.e., physical or chemical changes or reduced habitat effectiveness) in relation to a predefined area such as a mapped ecological unit (km^2 per km^2).

The diverse vegetation of the edge ecotone may contain a high density of birds, but a greater proportion of the individuals are juveniles, remain unpaired, experience high nest failure, fledge fewer offspring in a breeding season, and have lower survival rates (reviewed in Culling and Anderson 2001). Through these processes, edge habitat may act as an 'ecological sink' for forest interior bird species.

Edge effects are more pronounced in small forest fragments, since the ratio of edge to interior increases geometrically with decreasing forest size (Figure 4; Temple and Cary 1988; Collinge 1996; Culling and Anderson 2001). In very fragmented forests, virtually all remaining habitat may be so close to an edge that no functional interior habitat remains (Figure 4; Temple and Cary 1988). In general, larger forests contain more forest interior and neotropical migrant species, while smaller forests have a higher density and diversity of edge and interior-edge specialists (Askins et al. 1990, citing numerous authors). As patch size decreases, bird species richness in isolated fragments frequently decreases and the likelihood of local extinction increases (reviewed in Collinge 1996).

Forest fragmentation has been implicated as an important factor in the decline of 'forest interior birds', species such as warblers that are dependent on forest core (Askins et al. 1987, 1990; Paton 1994; Flather and Sauer 1996). Research in small, isolated habitat fragments surrounded by agricultural and suburban landscapes have detected local extinctions (Askins et al. 1987). However, few clear patterns are apparent in landscapes fragmented by forestry, where older forest fragments are imbedded in a matrix of younger forests and clearings (reviewed in Harris and Reed 2002).

Edge-related impacts on forest interior bird species include increased nest predation and reduced reproductive success (Askins et al. 1990; Virkkala 1991; Roth and Johnson 1993; Paton 1994; King et al. 1996; Rosenberg et al. 1999; Flaspohler et al. 2001). These factors could affect the continued presence of rare species with low local abundance (Hockin et al. 1992; Riffell et al. 1996).

Edge habitats are not all created equal. The nest success of disturbance-dependent bird species can be profoundly impacted by local land-use practices and the type of landscapes in which the edge is embedded (Harris and Reed 2002). Agricultural and abrupt, permanent edges (e.g., wildlife openings, campgrounds) had nest predation rates nearly twice as high as those of more gradual edges where plant succession had occurred (e.g., treefalls, streamsides, gaps created by selective logging) (Suarez et al. 1997). Abrupt edges may have higher prey visibility and increased predator activity.

A North America wide study found that the probability of finding cowbirds (nest parasites) increased with the degree of forest fragmentation and with lower elevation (Rosenberg et al. 1999). In general, nest parasitism rate was higher at more fragmented sites, but both of these results were somewhat variable across the wide area studied (Rosenberg et al. 1999). Other authors have also reported site-specific deviation from the general trend of elevated nest predation and parasitism rates at forest edges (Rudnicky and Hunter 1993; Yahner et al. 1993; Hahn and Hatfield 1995; Suarez et al. 1997; Tewksbury et al. 1998; Hannon 2000; Harris and Reed 2002).

A general theory emerging from the literature is that avian nest success is influenced by nest predator community composition and landscape structure on a relatively local scale (Virkkala 1991; Seitz and Zegers 1993; Yahner et al. 1993; Paton 1994; Darveau et al. 1997; Suarez et al. 1997; Tewksbury et al. 1998; Rosenberg et al. 1999; Bayne & Hobson 2000; Flaspohler et al. 2001). For instance, red squirrel (*Tamiasciurus hudsonicus*), a common nest predator, decreased with fragmentation of riparian forest in Montana (Tewksbury et al. 1998), but increased with fragmentation of boreal mixedwood forest in Saskatchewan (Bayne and Hobson 2000). Within an area, the net effect of increased fragmentation on predation rates will vary depending on prey availability, the regional abundance of forest-interior versus edge-adapted predators, the relative contribution of each group to overall predation rates, and the degree of fragmentation and types of edges found across the landscape (Culling and Anderson 2001).

4.1.3.1 Edge Widths

In coastal forest areas, microclimatic edge effects extend 100 m to 200 m into adjacent stands (BCF and BCE 1995a). Studies using artificial nests to investigate edge effects found predation and parasitism rates to be highest at the immediate edge, decreasing toward the forest interior (reviewed by Paton 1994). Biotic edge effects were most consistently found within 50 m of the forest edge (Paton 1994); research also suggests that abiotic and vegetation changes most consistently occur within 50 m of the forest edge (Paton 1994 citing several authors). Along clearcut edges in a heavily forested landscape, some species (Least Flycatcher [*Empidonax minimus*], Scarlet Tanager [*Piranga olivacea*] and Red-eyed vireo [*Vireo olivaceus*]) rarely nested within 50 m of the edge, while species commonly associated with edge and open canopy forest habitat (American Robin [*Turdus migratorius*], Rose-breasted Grosbeak [*Pheucticus ludovicianus*]) reached their highest nest abundance 50 m from the edge (Flaspohler et al. 2001).

The probability of nest survival was significantly decreased with distance to forest edge for ground-nesting birds (King et al. 1996; Flaspohler et al. 2001); canopy-nesting species were not impacted by distance to edge. However, all birds had higher nest density within 0 to 300 m than 301 to 950 m from the forest edge, suggesting that edges may be an ecological trap for sensitive species (Flaspohler et al. 2001). Flaspohler et al. (2001) suggest that the edge effect on nesting success for ground-nesting birds may extend 300 m into undisturbed forest; the effect of edge on nest density may extend further. King et al. (1996) concluded that ovenbird productivity may be reduced within a 200 m zone adjacent to small-scale clearcuts in forested landscapes. Temple and Cary (1988) report

82% nest failure in areas <100 m from the forest edge; 42% failure in areas 100 to 200 m from the edge; and 30% failure in areas >200 m from the edge respectively in 13 species studied in Wisconsin forests.

Edge ZOI detected for specific species are summarized in Table 4. The size and shape of the edge area depends on the sensitivity of the target species, the matrix surrounding the disturbance, and the intensity and duration of the activity. For example, predation rates on birds may be increased closer to the edge of clearings in agricultural areas (e.g., Sandstrom 1991), but edge effects may not occur in forested landscapes (Rudnicky and Hunter 1993). Effects of trails, pipelines, and cutlines are similar to roads, but the magnitude and ZOI of effects tend to be smaller for these narrow corridors because they are less physically disruptive and generally receive less human use (reviewed in Jalkotzy et al. 1998).

Table 4. Edge use guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Edge Use	▪ Deer used areas within 100 m of roads less than other areas, but no reduced use was evident at 600 m (Perry and Overly 1977)	▪ Based on studies in Oregon.
	▪ Elk and deer use highest within 180 m (Thomas et al. 1979).	▪ Based on studies in Oregon.
	▪ Forest bird productivity reduced within 100 to 200 m of high traffic roads (Reijnen and Foppen 1994; Reijnen et al. 1995).	▪ Based on studies in Netherlands.
	▪ Grizzly bear consistently under-use habitat within 500 m of high use roads; most grizzly bear mortality occurs within 500 m of roads and facilities and 200 m of backcountry facilities and trails (Mattson 1993; Gibeau et al. 1996; Mace et al. 1996; ESGBP, 1998).	▪ Based on work in Banff National Park, Montana, and Greater Yellowstone Ecosystem.
	▪ Boreal ecotype woodland caribou under-used areas <500 m of old wells during late winter and calving <250 m of these same features during summer; they also under-used areas <250 m of roads and <100 m of cutlines during late winter (Dyer 1999).	▪ Based on studies in north central Alberta.
	▪ Northern ecotype woodland caribou under-used areas adjacent to roads and streams but not cutlines (Oberg 2001).	▪ Based on studies in Alberta foothills adjacent to British Columbia border.
	▪ Predation rates for caribou may be higher <500 m of linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000).	▪ Based on studies in north central Alberta.
	▪ Elk and moose may avoid linear features and ground-based disturbance by 100 m to 500 m (Penner and Duncan 1983; Ferguson and Keith 1982).	▪ Based on studies in Alberta.
	▪ Forest interior songbird relative abundance was reduced adjacent to paved secondary roads and powerline rights-of-way, but not unpaved trails (Rich et al. 1994).	▪ Based on study in eastern pine-oak forest.

4.1.3.2 Disturbance Buffers

While proposed or observed disturbance buffers are not thresholds in the sense used here, they are common management tools that help define the edge area (or ZOI). Some examples are summarized in Table 5.

Table 5. Edge area/disturbance buffer guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Disturbance Buffer	▪ **Identified wildlife buffers** Bull trout = 500 m on each side of stream Trumpeter swan (*Cygnus buccinator*) = 200 m (BCF and MELP 1999a; OGC 2002).	▪ Recommended British Columbia buffers.
	▪ No access within 300 m of sensitive wildlife sites (WLAP Backcountry Recreation Guidelines 2002).	▪ Recommended British Columbia buffers.
	▪ Nesting bald eagles (*Haliaeetus leucocephalus*) generally avoided habitat <400 m from a stationary boat (McGarigal et al. 1991 *in* Jalkotzy et al. 1998).	▪ Study in Pacific Northwest; range of response varied from 200 to 900 m.
	▪ **Raptor Buffers** Osprey (*Pandion haliaetus*) = 1,000 m (range 400-1,500 m) Cooper's hawk (*Accipiter cooperii*) = 525 m (range 400-600 m) Northern goshawk (*Accipiter gentiles*) = 450 m Sharp-shinned hawk (*Accipiter striatus*) = 450 m Golden Eagle (*Aquila chrysaetos*) = 800 m (range 200-1,600 m) Red-tailed Hawk (*Buteo jamaicensis*) = 800 m Ferruginous Hawk (*Buteo regalis*) = 500 m (range 200-800 m) Bald Eagle = 500 m (range 250-800 m) Prairie Falcon (*Falco mexicanus*) = 650 m (range 50-800 m) Peregrine Falcon (*Falco peregrinus*) = 800 m (range 800-1600 m) American Kestrel (*Falco sperverius*) = 50-200 m (Richardson and Miller 1997).	▪ Based on review of recommended North American disturbance buffers.
	▪ Goshawks nested 550 m from nearest house on average (range 250 to 1000 m; Tommeraas 1993 in Jalkotzy et al. 1998).	▪ Based on study in Norway.
	▪ 97% of Ferruginous hawk and 78% of Swainson's hawk (*Buteo swainsoni*) nests were >500 m from the nearest farmyard (Schmutz 1982 in Jalkotzy et al. 1998).	▪ Based on study in Alberta.
	▪ Edge effects for interior forest birds occur <300 m from clearcut edge or road (Harris and Reed 2002).	▪ Based on literature review.

4.1.4 Core Area

Remaining **core area** is a widely used habitat index that identifies the availability and location of areas with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas that are often source areas for plant and animal populations or metapopulations.

In core areas, habitat effectiveness is enhanced for sensitive or 'interior' species such as grizzly bear, caribou, and warblers. Core area analysis is an accepted assessment technique for grizzly bear (Apps 1993; USFS 1993; Gibeau et al. 1996; Noss et al. 1996; CRC 1999) and has been adopted for other physical and ecological evaluations (Laurance and Yensen 1991; Reed et al. 1996b).

The abundance and diversity of forest-interior specialist and neotropical migrant bird populations is positively correlated with core forest area (Askins et al. 1990). Core area (defined as >100 m from the forest edge) was a better predictor of population abundance for forest interior bird species than total forest area (Temple 1986 *in* Askins et al. 1990). This was particularly true in forest sites with relatively little core area owing to their elongated or irregular shapes; predictions for these sites based on total forest area consistently overestimated abundances of interior species (Askins et al. 1990). Sites with long, narrow shapes, embedded open areas, and extensive linear corridors are less likely to be effective in preserving populations of forest-interior bird species, since they will have a higher edge to interior habitat ratio (Figure 5). The ideal configuration for forest preserves is solidly continuous and approximately circular (Askins et al. 1990; Collinge 1996).

Similar adaptations within forest-interior specialist and neotropical migrants may help explain their vulnerability to the high nest predation and parasitism rates associated with small forest patches. Compared to short-distance migrants and residents, they have a greater tendency to use open-cup versus cavity nests; to nest on or near the ground; and to have lower reproductive rates, with fewer broods/year and smaller clutch sizes (Askins et al. 1990 citing various authors). Hence, they are particularly vulnerable to predation and parasitism, and less likely to be able to compensate by renesting during the same breeding season (Askins et al. 1990).

In Canada, core areas have normally been defined to include those areas greater than a specified distance (often 500 m) from high use features (e.g., primary and secondary roads, truck trails, wellsites, petroleum and industrial facilities). A 500 m wide ZOI for all roads, wells, facilities, communities, and recreational sites is a conservative choice, since avoidance is generally related to activity levels rather than the features themselves (Mattson 1993; Dyer 1999; Gibeau 2000).

To be most effective, core areas should be larger than the minimum home range or territories of target species (Wilcove et al. 1986). Recommended and established core area thresholds are summarized in Table 6.

Table 6. Core area guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Core Area	▪ Minimize loss of core habitat (NCGBRT 2001).	▪ Recommendation for recovery of grizzly bear in the North Cascades of B.C.
	▪ No Net Loss of Core Area for grizzly bear (NCGBRT 2001).	▪ Grizzly bear management goal in the North Cascades of Washington.
	▪ >60% of available habitat as core area (Gibeau 2000).	▪ Grizzly bear management threshold for Banff National Park.
	▪ >58 to 68% of land area as core areas (NCGBRT 2001).	▪ Management goal for grizzly bear in Montana and Idaho National Forests.
	▪ >60% of Forest Planning Area as roadless core wildlife habitat (Horejsi 1996).	▪ Grizzly bear management recommendation for Yukon Territory.
	▪ Boreal-ecotype woodland caribou populations declined when core area <50%; threshold identified at <60% core area (Francis et al. 2002).	▪ Threshold based on review of Alberta population data; used 250 m buffer from all linear features.
Suitable Core Area	▪ Minimum viable core area of 450 to 1,000 ha (Gibeau et al. 1996).	▪ Grizzly bear core area used in western Canadian analyses based on 24 to 48 hr. feeding bout of an adult female grizzly.
	▪ Core area >10 ha in size, ideally >1,000 ha (NCGBRT 2001).	▪ Recommendation for recovery of grizzly bear in the North Cascades of B.C.
	▪ No vegetation change within established grizzly bear core areas for at least 11 years (USFS 1993).	▪ Management goal for Idaho National Forest.
	▪ Total weighted road density should be 0 km/km^2 in grizzly bear core areas (USFS 1993).	▪ Management goal for Idaho Nat'l Forest; Total Weighted Road density considers hiding cover, use intensity, and closure status to provide a common standard.

4.1.5 Patch and Corridor Indices

Clearing and other forms of natural and man-made disturbance introduce changes onto landscapes that affect the availability, distribution and juxtaposition of specific habitat types. These factors will influence population persistence, community composition, and ecosystem processes (Collinge 1996).

4.1.5.1 Patch Size

In forests of different sizes, the number of species and density of birds is similar, but the bird community composition is consistently different (Askins et al. 1987; Schmiegelow et al. 1997). Large tracts of forest contain greater diversity and density of forest-dwelling neotropical migrants than do small forest patches (Askins et al. 1987; Askins et al. 1990; Friesen et al. 1995; Schmiegelow et al. 1997). Dominant species in small forest patches tend to be widespread permanent residents and short-distance migrants (Askins et al. 1990). In general, the smaller the forest patch, the less effective it is as a preserve for forest interior specialists (Askins et al. 1990).

Reduced patch size may affect bird populations through some or all of the following mechanisms: (1) a decrease in the area of suitable habitat; (2) isolation of habitat patches, leading to reduced immigration/emigration and increased probability of local extinction; and (3) increased exposure to negative biotic factors affiliated with small patch size like brood parasitism and predation (Lord and Norton 1990; Boulinier et al. 1998 citing several authors; Rosenberg et al. 1999).

A short-term effect of forest fragmentation is a density increase in surrounding areas, as birds are displaced from the lost/altered habitat (Darveau et al. 1995; Hagan et al. 1996; Schmiegelow et al. 1997; Hannon 2000); this may create intense competition and attract predators, leading to high nest predation rates (Hagan et al. 1996). Bird densities will eventually decline and reductions will be faster and more extensive in smaller (Bierregaard & Lovejoy 1989 *in* Hagan et al. 1996) or narrower fragments (Darveau et al. 1995). Studies in the boreal forest found forest interior bird density declined below pre-fragmentation levels for 2 to 3 years following harvest, while the density of generalist species was unchanged (Darveau et al. 1995; Schmiegelow et al. 1997).

Reduced reproductive success may result from habitat fragmentation (Donovan et al. 1995a). Nest failure rates for three interior 'area-sensitive' species (Ovenbird [*Seirurus aurocapillus*], Wood Thrush [*Hylocichla mustelina*], and Red-eyed Vireo) were significantly higher in fragments than contiguous forests (Donovan et al. 1995a). In extensive forests, Ovenbird territorial male densities were higher (Villard et al. 1993); pairing success was higher (Porneluzi et al. 1993; Villard et al. 1993; Hagan et al. 1996); more nests were built (Hagan et al. 1996); more males successfully reproduced (Porneluzi et al. 1993); and more young were fledged (Porneluzi et al. 1993) than in fragments.

Habitat fragmentation may increase the temporal variability of communities through increased rates of local extinction and colonization (Boulinier et al. 1998). Over 22 years, larger forest patches in the eastern United States contained significantly more species and experienced less variation in the number of area-sensitive species present (Boulinier et al. 1998).

4.1.5.2 Patch Isolation and Habitat Heterogeneity

Patch isolation and habitat heterogeneity, including the presence of important microhabitats, also influence species richness in an area. Askins et al. (1987) found that large (≥72 ha) eastern forests contained significantly more bird species as the amount of forest in the surrounding area increased. Clusters of wetland marshes (individually 20 to 30 ha) contained more species than large, isolated marshes (up to 180 ha), perhaps due to increased habitat heterogeneity (Brown and Dinsmore 1986). These mechanisms interact with one another; for instance, fragment size is more critical with increasing isolation (Lord and Norton 1990).

4.1.5.3 Patch and Corridor Guidelines

Patch size must be adequate to sustain enough territories for a viable breeding population (Askins et al. 1990). Many migrant songbirds are territorial so population size may be regulated by the number of nesting territories within an area (Donovan et al. 1995b citing several authors). Askins et al. (1987) reported that several bird species were restricted to forest patches significantly larger than would be expected if they were randomly distributed. These minimum patch sizes were much larger than the territory sizes of the species concerned (Whitcomb et al. 1981 *in* Askins et al. 1990; Askins et al. 1987; Collinge 1996). The Biodiversity Guidebook (BCF and BCE 1995a) specifies 600 m as the minimum width required for interior forest conditions to develop; however, this 113 ha area may substantially underestimate the needs of some sensitive forest interior species (Askins et al. 1987).

In remnant riparian vegetation corridors, species diversity and abundance was affected by corridor width. Interior forest species (e.g., golden-crowned kinglet [*Regulus satrapa*], Swainson's thrush [*Catharus ustulatus*], blackpoll warbler [*Dendroica striata*], and black-throated green warbler [*D. virens*]) were less abundant than widespread species in 20 m wide corridors; these species appeared to require riparian corridors >60 m wide (Darveau et al. 1995). In boreal mixedwood forests of Alberta, 100 m wide riparian buffers along clearcuts maintained adult movements and enhanced juvenile dispersal (Machtans et al. 1996).

Quantitative guidelines for size and geometry of habitat patches and wildlife corridors have been developed and implemented within the Bow River Valley west of Calgary, Alberta. The Bow Corridor Ecosystem Advisory Group (BCEAG 1999a) established four classes of patches and corridors derived from a number of information sources, including some long-term field studies:

1. *Primary Corridor* – multi-species corridor that will accommodate the needs of animals wary of human activities and settled areas, including large carnivores.
2. *Secondary Corridor* – multi-species corridor that will accommodate the needs of smaller wildlife species and those more tolerant of human activities and developments (e.g., elk, deer).
3. *Regional Habitat Patch* – area large enough (>1,000 ha) to contain adequate resources to support large carnivores for short periods of time; these areas are generally incorporated within a protected area designation.
4. *Local Habitat Patch* – contains adequate resources to meet the food, water, and rest needs of an animal travelling to a larger, regional habitat patch. Local habitat patches contain sufficient interior (core) habitat for an animal to feed or rest with security from human disturbance.

Table 7 and 8 summarize additional patch and corridor guidelines, respectively from field studies and literature reviews.

Table 7. Patch guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Patch	Shrub or treed patches 0.8 to 2 ha optimum for deer thermal cover (Thomas et al. 1979).	Based on literature review and studies in Oregon.
	>4.5 ha patch area for small and tolerant species (BCEAG 1999a).	Based on literature review and local studies.
	4.5 ha circular patch area optimum for elk and deer (Thomas et al. 1979).	Based on literature review and studies in Oregon.
	<10 ha patches have higher nest predation rate (Paton 1994).	Based on literature review.
	up to 24 ha undisturbed area for trumpeter swan (BCF and MELP 1999a).	Recommended British Columbia core area.
	>400 m patch radius for mountain-ecotype woodland caribou (Bloomfield 1979).	Recommendation based on study in west central Alberta.
	>40 ha of suitable habitat in patch for persistence of black-throated green warbler (Hannon 1992).	Based on studies in central parkland of Alberta.
	>40 ha woodlot for bald eagle roosts (Buchler et al. 1991 *in* Jalkotzy et al. 1998)	Based on study in Washington State.
	>100-200 ha of suitable habitat in a patch for marten (*Martes americana*; Buskirk and Ruggiero 1994).	Based on literature review.
	200 ha undisturbed area for bull trout (BCF and MELP 1999a).	Recommended British Columbia core area.
	Optimum patch size based on protection of 20 to 25 breeding pairs (Lamberson et al. 1994).	Spotted owl (*Strix occidentalis*) reserve design.
	Minimum (Average) Patch Size Black-throated green warbler 187 ha (354 ha) Worm-eating warbler (*Helmitheros vermivorus*) 23 ha (477 ha) Brown creeper (*Certhia americana*) 50 ha (818 ha) Hermit thrush (*Catharus guttatus*) 323 ha (791 ha) Yellow-throated vireo (*Vireo flavifrons*) 347 ha (1366 ha) Cerulean warbler (*Dendroica cerulea*) 647 ha (1634 ha) (Askins et al. 1987)	Based on studies in Connecticut mixedwood forests.
	>183 ha in patch for functional breeding ovenbird population (Porneluzi et al. 1993).	Based on studies in eastern Pennsylvania.
	>1,000 ha patch area for carnivores and sensitive species (BCEAG 1999a).	Based on literature review and local studies.

Table 8. Corridor width guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Habitat Corridor Width	- >200 m corridor width for moose (Nietfeld et al. 1985).	- Based on literature review.
	- >350 m corridor width for all species (BCEAG 1999a).	- Based on literature review; can be adjusted using prescribed formula to reflect security provided by vegetation and topography (BCEAG 1999a).
	- >400 m corridor width for mountain-ecotype woodland caribou (Bloomfield 1979).	- Recommendation based on study in west central Alberta.
	- Minimum Riparian Width Warbling vireo (*Vireo gilvus*) = 90 m Wood thrush = 145 m Blue-gray gnatcatcher (*Polioptila caerulea*) = 150 m Ovenbird = 175 m Scarlet Tanager = 200 m American Redstart (*Setophaga ruticilla*) = 200 m Rufous-sided Towhee (*Pipilo erythrophthalmus*) = 200 m (Stauffer and Best 1980).	- Based on study in Iowa.
	- >600 m width for interior forest habitat conditions to be present (BCF and BCE 1995a).	

4.1.5.4 Fragmentation Analyses

Fragmentation analyses are similar to land use analyses described later in Section 5, but consider the attributes of the matrix rather than the disturbance features themselves. Patch indices include: patch size, number, density, perimeter, frequency distribution, interpatch distance (McGarigal and Marks 1995), cohesion and contagion (a measure of clustering; O'Neill et al. 1988 and Schumaker 1996 *in* Gustafson 1998), structural contrast (magnitude of difference between adjacent habitats), and juxtaposition measures (i.e., percentage of area within a defined distance from patch of different habitat types).

Basic fragmentation analyses can be done within a number of GIS software packages. More sophisticated analysis can be undertaken using commercial software such as FRAGSTATS and UTOOLS, which were developed specifically to assess fragmentation (McGarigal and Marks 1995; Ager and McGaughey 1997). These programs generate a comprehensive suite of landscape and patch metrics, that can help assess specific analysis objectives (Reed et al. 1996a,b).

4.2 POPULATION INDICATORS AND THRESHOLDS

Population indicators are frequently used to manage populations of harvested species. Application of population indicators and thresholds is complicated by the inherent variability of fish and wildlife populations. Figure 11 provides a theoretical example of how population-based ecological thresholds can be developed and applied.

Human disturbances can change the population dynamics of species in the ZOI. Disturbances that change mortality, fecundity (recruitment), immigration, and/or emigration rates can affect the size, distribution, and/or viability of local fish and wildlife populations.

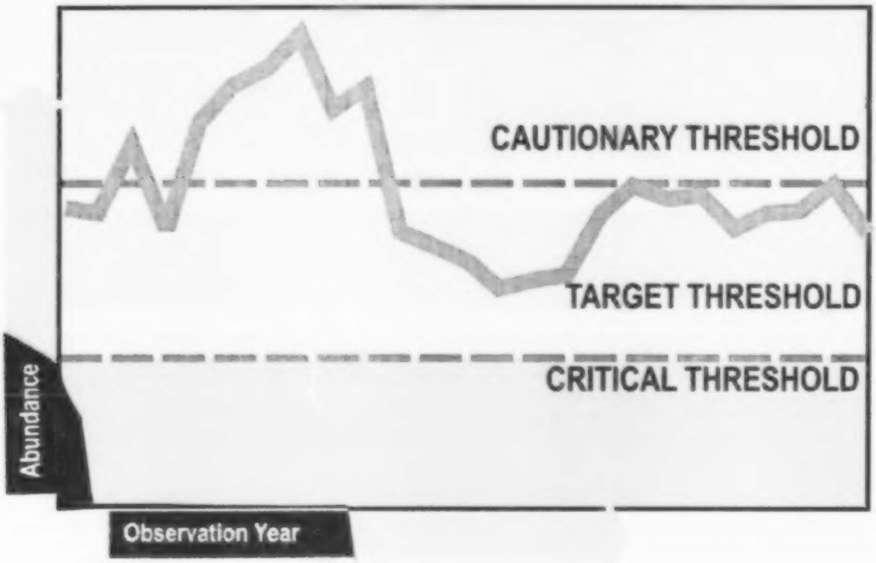

Figure 11. Tiered population thresholds.

Fish and wildlife managers conduct long-term monitoring of populations using a variety of standardized survey techniques. Field data on species and life history stages caught or observed are analyzed to determine distribution, relative abundance or density. These data provide useful information on historical and current trends and in theory, can also be used to monitor response to disturbance and habitat changes (Salmo et al. 2001). Numerical thresholds can be developed for most population parameters as summarized in Table 9.

Much early work to evaluate the ecological effects of human disturbance emphasized population indices such as abundance, population size, or density for indicator species or guilds. As noted in Section 2.2.2, population size is variable even under natural conditions, and this variability makes analyses of population parameters problematic for assessment and monitoring purposes (Karr and Chu 1997).

Table 9. Population guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Population Size	▪ Minimum viable population. ▪ Minimum population in defined area (e.g., 1,800 moose in a specified Management Unit). ▪ Average population calculated over defined interval. ▪ Maximum population in defined management unit. ▪ Minimum number of animals or redds detected during standardized field surveys (e.g., amphibian calls detected at more than 25% of survey sites). ▪ Minimum or average catch/harvest per unit effort. ▪ Species presence (e.g., designated invasive plants present on no more than 2% of area).	
Population Parameters	▪ Minimum or target cow:calf ratio. ▪ Defined age class composition. ▪ Minimum or defined sex ratio. ▪ Defined productivity (kg/ha).	

Population indicators are most useful for wildlife management at the regional scale or sport fish management in individual waterbodies. They have more limited utility for project-specific cumulative effects assessment since they require substantial supporting data and longer lead times, and are at best indirectly linked to proposed development activity. Project-specific studies generally emphasize habitat availability or quality because this can be readily quantified for both current and future scenarios.

4.3 BIODIVERSITY INDICATORS AND THRESHOLDS

Biodiversity is the diversity of plants, animals, and other living organisms in all their forms and levels of organization. This includes the diversity of genes, species, and ecosystems, as well as the evolutionary and functional processes that link them. As natural ecosystems become increasingly modified by human activities, natural patterns of biodiversity become increasingly altered and the risk of losing native species increases. The greatest degree of disruption occurs from land conversion for urban and agricultural purposes. Managed forest lands can support varying levels of biodiversity depending on management practices (BCE and BCF 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Suites of metrics have frequently been used as indicators of biodiversity and ecosystem integrity. Examples include the aquatic Index of Biotic Integrity (Karr 1991; Karr and Chu 1997), and Bureau of Land Management biodiversity indicators (seral stages, fragmentation, special habitats, special areas, riparian zones, species mix and hardwoods, snags, dead and down material, special status animals, special status plants; CEQ 1993).

Biodiversity analyses are most commonly used to identify and protect areas that are either representative, or rare/unique with respect to biological diversity (e.g., Kavanagh and Iacobelli nd). BCF and BCE (1995a) note that biodiversity management depends on a coordinated strategy that includes:

- a system of protected areas at the regional scale,
- maintenance of a variety of patch sizes, seral stages, and forest stand attributes at the regional and landscape scales,
- maintaining connectivity to ensure the continued dispersal and movement of animals and plants between landscapes, and
- protection of sensitive sites and features at the local scale.

In British Columbia, biodiversity objectives are related to Natural Disturbance Types (NDTs) to reflect the frequency of stand-initiating events (BCF and BCE 1995a). Examples of biodiversity management guidelines are summarized in Table 10.

Table 10. Biodiversity management guidelines.

Indicator	Guideline or Threshold	Comments
Landscape Diversity	• Landscape Unit Plans, including biodiversity objectives (BCF and BCE 1995a; BCF and MELP 1999b).	• Already applied by the forest sector in northeast British Columbia.
	• System of regional protected areas (BCF and BCE 1995a).	• Established in northeast British Columbia through LRMP process.
	• Old growth and wildlife tree retention BCF and BCE 1995a; BCF and MELP 1999a,b).	• Forest harvesting generally increases the amount of young forest and decreases the amount of older forest. The more that managed forests diverge from natural disturbance regimes, the greater the risk of loss of biodiversity (BCF and BCE 1995a).
	• Seral stage objectives (BCF and BCE 1995a; BCF and MELP 1999b).	
	• Maintain riparian areas in mid- to upper-seral successional states (CEQ 1993).	
	• Increase diversity of structure and age classes of specified vegetation communities (CEQ 1993).	
	• Define forest ecosystem networks (BCF and BCE 1995a; BCF and MELP 1999b).	• To maintain landscape connectivity.
Species Diversity	• Management of identified wildlife species (BCF and MELP 1999a).	
	• Defined species composition (BCF and BCE 1995a; BCF and MELP 1999a).	
	• Defined community structure (top-level predators maintained; CEQ 1993).	

4.4 RISK-BASED INDICATORS AND THRESHOLDS

Population viability analysis can be used to predict the probability of extirpation (loss) or decline of a population over a certain specified time period.

Viability analyses can explicitly consider the unpredictability of life history and environmental events, relative to a population's status. For instance, litter sizes for a species may range from 1 to 4 but individuals vary within that range. Stochastic population models describe events such as reproductive rate in terms of both their average value and their variance (standard deviation). Population models incorporate factors with uncertain outcomes by randomly deciding the outcome within the limits specified by the variance associated with the factor. Types of 'stochastic' variables in a population simulation model include: sex determination, survival rates, reproductive rates, dispersal rates, mate selection, effects of inbreeding, number of offspring, and catastrophes and their effects. Input parameters can also be varied to determine the effect of an activity on the probability of population decline or extirpation; land use thresholds can then be defined from the model results (Salmo et al. 2001).

This approach has been applied to forest reserve design for protected species in the western United States (e.g., Lamberson et al. 1994; Table 11). MELP (2000) has also developed a risk-based approach to environmental assessment in British Columbia that is able to incorporate cumulative effects indicators.

Table 11. Risk-based guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Population Viability	▪ Negligible risk of extinction of a viable salmonid population over a 100-year time frame (McElhany et al. 2000). ▪ High probability of survival after 250 years, considering dynamic landscape and random factors (Lamberson et al. 1994).	▪ US National Marine Fisheries Service draft guide for salmon recovery.

Risk-based indicators are generally most appropriate where species of concern are the management focus. They also require substantial supporting data and longer lead times to calculate (Dugas and Stenhouse 2000; Rohner and DeMarchi 2000; Axys 2001b; BCC 2001; Salmo et al. 2001; Harris and Reed 2002).

5. LAND USE INDICATORS AND THRESHOLDS

Over the last 30 years, and particularly during the last decade, a wide array of **land use indices** have been developed and applied to fish and wildlife management. These indices document existing and future human disturbance features such as linear corridors (e.g., roads, seismic lines, rail lines, pipelines), clearings (e.g., cutblocks, agricultural fields), facilities (e.g., mines, gas plants, borrow pits, wellsites), residential (e.g., houses, communities), and recreational sites (e.g., campgrounds, trails). A GIS summarizes information on the location and intensity of use of these features to evaluate potential effects on fish and wildlife populations and habitat.

Land-use indices provide meaningful information about existing disturbance levels, the incremental effect of proposed activities, and potential cumulative effects from existing, planned, and potential future activities (Hegmann et al. 1999; Antoniuk 2002). They are generally input-based; examples include:

- access density (km/km^2; the total length of roads or other linear corridors present in a defined area),
- total cleared or disturbed area (ha),
- core area (area greater than a specified distance from a land use feature),
- edge area (area within a specified distance of land use feature),
- stream crossing index (number of crossings/km of stream),
- valley roads (length of roads and utility corridors within 100 m of a stream), and
- riparian area cleared (ha; area cleared within 15 m of a stream or lake bank).

Land-use thresholds have been applied in the northwest United States for management of species at risk such as grizzly bear and spotted owl (e.g., Lamberson et al. 1992; Mattson 1993; Bart 1995). In Canada, similar thresholds have been applied within national parks; research is underway to establish disturbance-based thresholds for grizzly bear and boreal-ecotype caribou in Alberta (Dugas and Stenhouse 2000; BCC 2001).

5.1 HUMAN ACTIVITY

Repeated intrusions by recreational users and other groups within bird habitat can seriously alter avian behaviour, habitat use, reproduction, and survival (Riffell et al. 1996; Richardson and Miller 1997; Rodgers and Smith 1997; Gutzwiller et al. 1998). Human intrusion can uncouple foraging relations within guilds (Skagen et al. 1991), decrease song occurrence and singing consistency (Gutzwiller et al. 1994 *in* Riffell et al. 1996), alter nest height and location (Datta and Pal 1993 *in* Riffell et al. 1996), compromise nest defense (Keller 1989 *in* Riffell et al. 1996; Richardson and Miller 1997 citing several authors), and reduce hatching and fledging success (Safina and Burger *in* Riffell et al. 1996; Richardson and Miller 1997 citing several authors; Gutzwiller et al. 1998). A recreational trail may have a ZOI up to 100 m into adjacent habitat (Miller et al. 1998 *in* Hamilton and Wilson 2001). Additive and synergistic effects from multiple disturbance sources can cause reductions in fitness, even when individual disturbance types have no impact (Holmes et al. 1993).

Responses to human intrusion vary considerably between and within bird species (Tuite et al. 1984; Skagen et al. 1991; Holmes et al. 1993; Rodgers and Smith 1997; Gutzwiller et al. 1998; Jalkotzy et al. 1998). In general, birds with larger bodies, higher up the food chain, or that feed in flocks tend to be more sensitive to disturbance (Hill et al. 1997). Repeated human intrusion can potentially cause impacts that accumulate over time, eventually manifesting as progressive declines in avian richness and abundance (Riffell et al. 1996). Experimentally, repeated intrusion over 5 years in 1 ha patches within a large contiguous forest caused significant declines year-to-year in relative richness and abundance of common bird species, but no cumulative declines were detected (Riffell et al. 1996).

Most bird species are sensitive to human disturbance at their nesting sites, and frequently exhibit physiological or behavioural responses. These responses may or may not result in long-term population effects (Hill et al. 1997). Potential population-scale effects include nest desertion, reduced parental care of young, decreased feeding efficiencies, and increased offspring dispersal distances (Richardson and Miller 1997; Jalkotzy et al. 1998 citing numerous authors). A common short-term response to disturbance is temporarily leaving the nest or perch ('flushing') in response to: unfamiliar noises (Owens 1977; Tuite et al. 1984), pedestrian approach (Owens 1977; Tuite et al. 1984; Fraser et al. 1985; Grubb and King 1991; Skagen et al. 1991; Holmes et al. 1993; Riffell et al. 1996; Rodgers and Smith 1997; Gutzwiller et al. 1998); aircraft/ boat/ATV passage (Davis and Wiseley 1974; Owens 1977; Tuite et al. 1984; Grubb and King 1991; Rodgers and Smith 1997); and vehicular traffic (Grubb and King 1991; Holmes et al. 1993; Rodgers and Smith 1997).

Response distances vary considerably, and may be influenced by:

- body size (Holmes et al. 1993),
- degree of 'conspicuousness' (Gutzwiller et al. 1998),
- reproductive status (Bromley et al. 1995; Rodgers and Smith 1997),
- perch/nest height (Holmes et al. 1993; Gutzwiller et al. 1998),
- avian group size (Owens 1977; Belanger and Bedard 1989; Skagen et al. 1991; Gutzwiller et al. 1998), and
- dominant vegetation/landscape type (Rodgers and Smith 1997; Hill et al. 1997).

Human habitation appears to reduce habitat suitability for some raptor and songbird species. As the number of houses within 100 m of a forest edge increased, the diversity and abundance of neotropical migrant songbirds decreased, regardless of forest size (Friesen et al. 1995). They found that a 25-ha urban woodlot had a poorer, less abundant neotropical community than did a 4-ha woodlot without residences nearby. Both species diversity and individual abundance sharply declined with an increase from 8 to 15 residences to ≥25 residences adjacent to the forest studied (Friesen et al. 1995). Raptor nests are normally >250 m from houses (reviewed in Jalkotzy et al. 1998).

Human activity guidelines and thresholds and flushing distances are summarized in Table 12.

Table 12. Human activity guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Human Activity	▪ No trails within designated wildlife corridors (BCEAG 1999b).	▪ Guideline for Bow Corridor near Canmore, Alberta.
	▪ <30 km of linear corridors active in any township at any given point in time each year between December 1 and April 30 (Pedigree Caribou Standing Committee 1991).	▪ Threshold developed for woodland caribou in northwest Alberta.
	▪ Restrictions on bus and private vehicle passage (Singer and Beattie 1986).	▪ Traffic control in Denali National Park, Alaska.
Pedestrian Flushing Distance	▪ Mean flushing distance Golden eagle = 225 m (Holmes et al. 1993). Bald eagle = 338 m (Skagen et al. 1991); = 476 m (Fraser et al. 1985 *in* Jalkotzy et al. 1998). Rough-legged hawk (*Buteo lagopus*) = 177 m (Holmes et al. 1993). American kestrel = 44 m (Holmes et al. 1993). Merlin (*Falco columbarius*) = 76 m (Holmes et al. 1993). Great Blue heron (*Ardea herodias*) = 31 m (Rodgers and Smith 1997). American crow (*Corvus brachyrhynchos*) = 202 m (Skagen et al. 1991). Gray jay (*Perisoreus canadensis*) = 9 m (Gutzwiller et al. 1998). Mountain chickadee (*Parus gambeli*) = 4 m (Gutzwiller et al. 1998). American robin = 12 m (Gutzwiller et al. 1998). Yellow-rumped warbler (*Dendroica coronata*) = 9 m (Gutzwiller et al. 1998).	
Vehicle Flushing Distance	▪ Mean flushing distance Golden eagle = 82 m (Holmes et al. 1993). Bald eagle = 50 to 990 m (Fraser et al. 1985 *in* Jalkotzy et al. 1998). Rough-legged hawk = 71 m (Holmes et al. 1993). American kestrel = 40 m (Holmes et al. 1993). Merlin = 62 m (Holmes et al. 1993). Western sandpiper (*Calidris mauri*) = 19 m (Rodgers and Smith 1997).	
Boat Activity Distance	▪ Mean flushing distance Goldeneye (*Hiodon alosoides*) = >700 m (Hume 1976 *in* Tuite et al. 1984).	

5.2 HUMAN-CAUSED MORTALITY

Human-caused mortality results from legal and illegal harvest, trapping, management actions (e.g., problem wildlife control, defence of life and property), and vehicle collisions. Human activities and structures may also indirectly increase mortality; but detection and assessment of this mortality is difficult. For example, road construction causes limited or no direct mortality, but the road can increase mortality rates by increasing harvest effort and success. Increased mortality is a concern for species with low reproductive rates and limited ability to rebound from population declines (Ursus and Salmo 2002).

Vehicle collisions can be a significant mortality source for some species. In general, mortality increases with traffic volume (Trombulak and Frissell 2000). Often, high mortality road-kill locations are associated with substantially higher quality feeding opportunities available along the roadside (Gibeau and Heuer 1996; Lehnert et al. 1996). Annual road-kill and train-kill mortality rates for carnivores in the Banff Bow Valley were: coyotes (*Canis latrans*) - 25%, black bear (*Ursus americanus*) – 9 to 11%, cougar (*Felis concolor*) – 3 to 5%, and grizzly bear – 0% (Gibeau and Heuer 1996). Road-kill mortality is a serious concern for low-density populations (e.g., cougar) particularly because it is additive with natural mortality, management removal, and hunting mortality (Gibeau and Heuer 1996). Road-kill can have substantial demographic effects, particularly because it kills regardless of age, sex, or condition of the animal (Trombulak and Frissell 2000).

Examples of mortality guidelines are provided in Table 13.

Table 13. Mortality guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Mortality	▪ <4% grizzly bear harvest rate from all sources; females should be <33% of total kills, including estimated natural mortality, accidental kills, and illegal kills (MELP 1995).	▪ Sustainable harvest rate for British Columbia.
	▪ 40% hunter success rate with moose killed for every 15 days hunted (Harper 1988).	▪ Recommended management objective for northeast British Columbia.
	▪ <1% average annual mortality based on current population estimate (Gibeau et al. 1996).	▪ Recommendation for grizzly bear in Banff National Park.

5.3 ACCESS DENSITY

Roads and access corridors are of increasing concern for terrestrial and aquatic communities (Trombulak and Frissell 2000). Research indicates that some animals avoid, and are displaced by disturbances associated with roads. In addition, there is a tendency for trails and roads to be extended beyond their original destination, ultimately creating an access network. In many cases, it is difficult or impossible to manage these incremental impacts after the original access route is in place (Mychasiw and Hoefs 1988).

5.3.1 Observed Effects

Figure 7 illustrated the inverse relationship between access density and elk habitat effectiveness for a variety of road types. Actual terrestrial effects of linear corridors are complex and vary with species, sex, vegetative and topographic features of the landscape, prior exposure to disturbance, traffic volume and patterns, season, and hunting history (PRISM 1982; O'Neill 1993; Mace et al. 1996; Jalkotzy et al. 1998; Gibeau 2000). For instance, roads are commonly assumed to have a negative effect on moose at the local scale, at a regional scale, road density was positively associated with moose density in northern Alberta (Schneider and Wasel 2000). Some species can partly habituate to activities associated with roads, and reduce their behavioural reaction to them, but this does not occur in all cases (Mychasiw and Hoefs 1988).

Access effects on most wildlife species appear to be related to traffic volumes, out-of-vehicle activity, and predation rather than the linear feature itself. For example, roads through meadows have greater impact on elk and deer than roads through forests due to the visual screening provided by forest cover (Perry and Overly 1977). Vehicle traffic influenced caribou crossing success more than the presence of elevated pipelines and roads (Murphy 1984). Humans and stopped vehicles generally elicit a greater response than moving vehicles and other mechanical disturbances (Singer and Beattie 1986; Henson and Grant 1991; Andersen et al. 1996).

In Denali National Park, Alaska, a 50% increase in traffic volume on the sole access road reduced moose and grizzly bear sightings by 72% and 32% per trip, respectively. Caribou and Dall sheep (*Ovis dalli dalli*) sighting rates were unchanged, and relative abundance of all species was considered to be similar. The most severe responses occurred when visitors left their vehicles and approached animals (Singer and Beattie 1986).

In northern Montana, most grizzly bears exhibited a neutral or positive response to roads receiving less than 10 vehicles per day (300 per month), but avoided roads with higher traffic volumes. Grizzly bears can persist in areas with roads, but spatial avoidance increases and survival decreases as traffic levels, road densities, and human settlement increase. Average total road density was 0.6 km/km^2 in areas used by female bears as compared to 1.1 km/km^2 outside the composite home range. In this analysis, total road density included roads both open and closed to vehicle traffic, but excluded old roads reclaimed by natural vegetation or 'in-block' roads in timber harvest units (Mace et al. 1996). In southeast British Columbia, grizzly bears selected lower elevation riparian areas with average road density of 0.68 km/km^2 during spring and fall (McLellan and Hovey 2001). Mace et al. (1996) frequently found grizzly bears in regenerating cutblocks but these features were consistently selected less than other habitats in the Flathead valley (McLellan and Hovey 2001).

Caribou provide a good example of the variability in observed response. As noted above, caribou exposed to non-threatening behaviour in Denali Park did not appear to avoid a heavily used road (Singer and Beattie 1986). Barren ground caribou in other parts of Alaska appear to avoid roads where they are hunted (USBLM 1997). Habitat use of female barren ground caribou was altered by petroleum development during the calving and post-calving period; males and juveniles did not display the same response (Cameron et al. 1992; Nellemann and Cameron 1995; USBLM 1997). The local distribution of caribou on the calving grounds appears to be related to predators and insects (Cameron et al. 1992). In north central Alberta, boreal-ecotype caribou used areas adjacent to roads less than expected; this response was independent of the level of activity (Dyer 1999).

5.3.2 Road Density

Road density can be used as a numerical indicator of the habitat effectiveness and fragmentation associated with linear corridors. It is a useful summary index because it integrates so many ecological effects of roads and vehicles (Forman and Hersperger 1996). Relationships between access density and habitat effectiveness have been developed for some large mammals (e.g., Thomas et al. 1979, 1988; Lyon 1983,1984; Thiel 1985; Mace and Manley 1993; Reijnen and Foppen 1994; Mace et al. 1996; Jalkotzy et al. 1997; Rowland et al. 2000). Access density is commonly used for cumulative effects assessments in western Canada (e.g., CRC 1999; Alliance 1997; Hegmann et al. 1999; Kansas and Collister 1999), but the linear features considered to represent access may vary.

In aquatic evaluations, road density has been used as an indicator of land use and forestry activity and cumulative effects risk (BCF and BCE 1995b; Carver 2001). It has also has also been correlated with declines in salmonid species, including bull trout (USDA 1996; Rieman et al. 1997; Baxter et al. 1999). Roads may also increase the vulnerability of fish populations to other impacts like illegal harvest and non-native species introduction (Baxter et al. 1999; BCF 1999). The use of road density in watershed analyses is discussed in Section 5.5.

'**Open road density**' is an indicator that factors in the effect of road closures and revegetation that reduce actual use of roads and trails. An open road is defined as a linear feature that is passable by any type of four-wheel motorized vehicle and that is not closed to public use by gates or other methods. Formal definitions of closed roads vary; examples include roads that receive less than 5 round trips per week, and roads where use is restricted to one or two very short periods (<14 days total) during the year (Servheen 1993).

Established road and open road density effects, guidelines, and management thresholds are summarized in Table 14.

Table 14. Road density guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Road Density	Road density <0.6 km/km^2 to protect high quality grizzly bear habitat (BCF and MELP 1999a).	Recommended British Columbia threshold.
	Density of calving barren-ground caribou highest at road density of 0 km/km^2 and declined by 86% at road densities >0.6 km/km^2; male and yearling density highest at 0.3-0.6 km/km^2 (Nellemann and Cameron 1998).	Based on studies in Alaska petroleum development areas.
	Road densities <0.6 km/km^2 in winter range used by northern-ecotype caribou (Salmo unpub. data).	Based on studies in west central Alberta.
	Road densities greater than 0.6 km/km^2 may affect habitat usage by wolves and elk (Lyon 1983, 1984; Thiel 1985; Edge and Marcum 1991; Mech 1989; Rowland et al. 2000).	Effects can be mitigated by the presence of visual barriers and adjacent unroaded areas.
	Areas selected by grizzly bears had average road densities of 0.6 to 0.68 km/km^2 (Mace et al. 1996; McLellan and Hovey 2001).	Based on studies in northern Montana and southeast British Columbia.
	Areas with road densities greater than 6 km/km^2 do not support grizzly bears (Mace et al. 1996).	Based on study in northern Montana.
	Forest Operating Area with road density >1.25 km/km^2 on <10% of area and additional 10% up to 0.6 km/km^2 (Horejsi 1996).	Forest harvest management recommendation for grizzly bear in Yukon Territory.
	<30% of Forest Operating Area with road density <0.3 km/km^2 (Horejsi 1996).	Forest harvest management recommendation for grizzly bear in Yukon Territory.
	Road density <1.5 km/km^2 to protect bull trout (BCF and MELP 1999a).	Recommended British Columbia threshold; additional site-specific work required beyond this point.
	Bull trout populations were seven times more likely to be strong in subwatersheds with road densities <1.55 km/km^2 (Rieman et al. 1997).	Based on study in interior watersheds in Pacific Northwest United States.
	Watershed road densities >2.5 km/km^2 increased sediment yield and affected downstream spawning habitat (Cederholm et al. 1981).	Based on study in coastal watershed in Pacific Northwest United States.
	0 to 0.06 km/km^2 Very Low; 0.06 to 0.4 km/km^2 Low; 0.4 to 1.1 km/km^2 Moderate; 1.1 to 2.9 km/km^2 High; >2.9 km/km^2 Very High (Quigley et al. 1996).	Rankings established for Interior Columbia basin in Pacific Northwest United States.
	0 to 0.9 km/km^2 Low; 0.9 to 1.72 km/km^2 Medium; >1.72 km/km^2 High Aquatic Hazard (BCFS and BCE 1995).	Aquatic hazard rating developed for British Columbia.
Open Road Density	Average open road density <0.45, <0.48, or <0.6 km/km^2 (Servheen 1993).	Management objectives in 3 Yellowstone Grizzly Bear Recovery Zone National Forests.

Information provided in Table 14 demonstrates that cumulative effects risk increases along with road density. Females, especially those with young, are generally less tolerant of roads than males. Areas with few or no roads (i.e., less than 0.6 km/km^2) appear to be critical for long-term persistence of intolerant species such as woodland caribou, grizzly bear, and bull trout.

Models relating road density to terrestrial habitat effectiveness have been developed for a few species. Local circumstances have significant effects on actual species response, and models developed in other areas should be applied with caution:

- recent work to validate a commonly used elk-road model confirmed that elk avoid roads during spring and summer, but that the model overestimates the relative loss of habitat effectiveness (Rowland et al. 2000),
- differences in response of grizzly bears may reflect the amount of use that roads receive. In southeast British Columbia, high grizzly bear densities occurred in areas with higher open road densities than observed in American studies (McLellan 1990; Servheen 1993). However, these roads receive very little use except during hunting season, while use is much higher in most areas of Montana, Idaho, Wyoming, and Washington with comparable road densities. Proximity to human population centres, ease of access, and actual road use intensity are therefore important factors (Servheen 1993), and
- many different definitions of roads, trails and human use intensity have been used, and results may not be directly comparable.

5.3.3 Corridor Density

Access effects on most wildlife species appear to be related to traffic volumes, out-of-vehicle activity, and predation rather than the physical presence of the feature. There is currently scientific and public debate on whether cutlines and utility corridors (pipelines, powerlines, railway lines) have the same impact as roads. Jalkotzy et al. (1998) reviewed available literature and concluded that the effects of these features are similar to those of roads, but that the magnitude of effects is lower since their physical attributes are less disruptive (e.g., narrower and more curvilinear) and fewer people use them.

Studies in relatively unpopulated areas of the Alberta foothills indicate that human use of cutlines, utility corridors, and trails is generally lower than previously thought, and that most would be classified as 'no-use' features for grizzly bear habitat effectiveness purposes (Kansas and Collister 1999; Salmo unpub. data). In the Wapiti River drainage immediately east of the provincial border, 35% of cutlines were classified as unpassable because of vegetation regrowth (Salmo unpub. data).

Although no clear relationship has been demonstrated, all types of linear corridors may increase predation by providing packed travel routes for wolves, thus increasing their search efficiency and range (Bergerud et al. 1984). This may be especially significant for woodland caribou. In north central Alberta, wolf predation rates for caribou were higher in proximity to linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000).

Boreal-ecotype caribou avoided cutlines in this area (Dyer 1999), but northern-ecotype caribou in west central Alberta did not (Oberg 2001).

Narrow linear corridors may act as filters or barriers to small mammals and songbirds (several authors cited by Machtans et al. 1996). Fleming and Schmiegelow (2002) observed that several bird species were unwilling to cross 15 to 16 m wide pipeline rights-of-way near Grande Prairie, although no effect on species number or abundance was detected. Desrochers and Hannon (1997) reported that gaps <30 m wide had little effect on bird movements, but gaps >70 m altered movement patterns significantly for some species. Dellasala (1986 *in* Jalkotzy et al. 1998) found that declines in density of Red-eyed vireo, a forest interior species, increased along with right-of-way width. The area affected by density declines also increased from 250 m adjacent to medium-width features, to 400 m adjacent to the widest rights-of-way.

'Corridor density' guidelines and thresholds were summarized in Table 15.

Table 15. Corridor density guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Access Corridor Width	▪ Forest interior songbird relative abundance was reduced adjacent to paved secondary roads (15 m) and powerline rights-of-way (23 m), but not unpaved trails (8 m); 10 m considered to represent the fragmentation threshold (Rich et al 1994).	▪ Based on study in eastern pine-oak forest.
	▪ No effect on bird community structure was detected adjacent to 15 m pipeline rights-of-way (Fleming and Schmiegelow 2002).	▪ Based on study near Grande Prairie.
	▪ No effect on small mammal abundance and distribution was detected adjacent to 5 m wide trails in idle pasture or dense nesting cover; an edge effect was detected in delayed hay fields (Pasitschniak-Arts and Messier 1998).	▪ Based on study in south central Saskatchewan.
Corridor Density	▪ Boreal-ecotype woodland caribou populations declined when total corridors >1.8 km/km^2 (Francis et al. 2002).	▪ Threshold based on review of Alberta population data.
	▪ Boreal-ecotype woodland caribou populations do not persist when total corridors >3 km/km^2 (B. Stelfox pers. comm.).	▪ Threshold identified by caribou biologists in Delphi process.

5.4 CLEARED/DISTURBED AREA

Total cleared or **disturbed area** is used as a numerical index of forest habitat availability and fragmentation. This index is the inverse of the available habitat indicator discussed in Section 4.1.1.

Natural and anthropogenic disturbances introduce changes into forest landscape patterns that affect the availability, distribution and juxtaposition of specific habitat types. Studies in temperate and tropical areas have shown a positive relationship between the number of species and the area of contiguous suitable habitat, and habitat destruction is assumed to be the major cause of species extinctions (e.g., Forman and Godron 1986; Seagle 1986; Tilman et al. 1994; Flather and Sauer 1996). However, moderate levels of forest fragmentation may benefit habitat generalists with good mobility (Enns et al. 1993; Bayne and Hobson 2000).

Cleared or disturbed areas may also create barriers to movement, (Wilcove et al. 1986), create movement corridors, and affect stream flow and quality (e.g., Troendle and King 1985; Nip 1991). Movement rates of forest interior songbird species were significantly lower in clearcuts than in adjacent forests (Machtans et al. 1996). They also concluded that there appeared to be a maximum distance (unspecified) between undisturbed areas, below which birds may be more willing to cross openings such as clearcuts.

Clearing and disturbance guidelines and thresholds are summarized in Table 16.

Table 16. Clearing and disturbance guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Cleared/Disturbed Area	▪ Sediment accumulation increases when road area is >2.5% of basin area (Cederholm et al. 1981).	▪ Recommendation to prevent sediment accumulation in coastal streams.
	▪ <5% of any township cleared (Pedigree Caribou Standing Committee 1991).	▪ Disturbance threshold developed for woodland caribou in northwest Alberta.
	▪ <300 km new linear corridors in any township during a single winter (Pedigree Caribou Standing Committee 1991).	▪ Disturbance threshold developed for woodland caribou in northwest Alberta.
	▪ 5% reduction in total forest area did not cause a detectable effect on relative abundance of forest interior songbirds, considered as a group; >10% reduction did (Rich et al. 1994).	▪ Based on study in eastern pine-oak forest.
	▪ <20% of watershed cleared within 10 years (Bosch and Hewlett 1982).	▪ Literature-based threshold to prevent detectable changes in streamflow.
	▪ <30 to 33% of watershed harvested within 25 years (Chatwin 2001).	▪ Threshold established for a number of British Columbia watersheds.

Theoretical and field investigations have identified critical thresholds in the process of habitat fragmentation where rapid changes in the size and isolation of patches occur (Andren 1994; With and Crist 1995; Mönkkönen and Reunanen 1999). As habitat becomes increasingly fragmented, the number of local extinctions increases. In remnant patches, even moderate habitat loss increases the extinction risk of abundant species, although there is a 50 to 400 year lag before this is predicted to occur (Tilman et al. 1994).

5.5 WATERSHED ASSESSMENT

Cumulative effects on watersheds can result from the accumulation of the insignificant effects of small routine activities, or from changes in dominant watershed processes (Collins and Pess 1997). Studies in western North America have shown that clearings and road and trail networks created for timber harvest and resource extraction can create direct and indirect effects on flow rates, patterns, sediment yield, stream habitat, invertebrates, and fisheries (Furniss et al. 1991; McGurk and Fong 1995; Trombulak and Frissell 2000). Several models and indices have been developed to describe these effects.

Investigators in Alberta, British Columbia, and the northwest United States have developed watershed assessment techniques that use watershed indices to evaluate the potential for cumulative aquatic effects from combined land uses in a watershed. Most cumulative effects techniques consider disturbed area, potential for sediment yield, water quality, or changes in probable peak flow and channel characteristics (Klock 1985; Reid 1993; Lowrence and Vellidis 1995; Lull et al. 1995; McGurk and Fong 1995; Collins and Pess 1997; Carver 2001).

Chatwin (2001) discusses six types of watershed assessment techniques that have been applied in British Columbia:

- process models,
- empirical models,
- expert systems,
- critical thresholds,
- indicator models, and
- professional assessments.

Process and **empirical models** simulate or predict specific hydrological or aquatic habitat attributes. They are most applicable to strategic planning or research and are impractical for routine watershed assessment purposes (Chatwin 2001; Salmo et al. 2001).

Expert systems are standardized evaluations developed from the collective knowledge of a group of experts. Non-technical users input predefined parameters into a workbook or computer program, which then provides a rating of risk or sensitivity. This approach was abandoned because it did not help define why or when more detailed investigations were appropriate (Chatwin 2001).

The concept of **critical thresholds** has been discussed extensively in preceding sections. In British Columbia, thresholds have been established to define the maximum percentage of watershed that can be cut over a set period of time (Table 16). A variant, Equivalent Clearcut Area is discussed in more detail in Section 5.5.1.

The British Columbia Level 1 Interior Watershed Assessment Procedure (IWAP) is an example of an **indicator model**. This procedure used thirteen indices calculated as part of reconnaissance level analysis to examine the potential for cumulative effects due to past or planned forest harvesting (BCF and BCE 1995b). This procedure was designed to be completed by non-specialists with basic map and airphoto skills. Indices were ultimately used to generate 'hazard levels' for peak flow, erosion (sediment), riparian condition, and landslides. Rating procedures and scores were developed by experienced hydrologists working with detailed data from 20 watersheds. IWAP results from 1,400 subwatersheds were reviewed by Carver and Teti (1998, *in* Carver 2001 and Chatwin 2001). They found that the distribution of hazard scores was reasonable and conservatively segregated watersheds into no problem and possible problem groups. It was also inexpensive, consistent and repeatable (Chatwin 2001).

Unfortunately, the IWAP provisions for site-specific data collection were not consistently implemented, and a 'Revised IWAP' was developed (BCF 1999) that emphasized **professional assessments** based on field work. This procedure is considered to be more reliable because it is unique to each watershed. However, it is significantly more expensive and less consistent and repeatable (Carver 2001; Chatwin 2001).

A Landscape Unit plan that integrates watershed, riparian, and biodiversity objectives, is currently being piloted in the Okanagan watershed; this is considered to be the next logical step in watershed assessment and management (Chatwin 2001).

Individual watershed indicators have poor predictive power, especially when applied to large geographic areas with variable geological, climatic, and hydrological conditions. However, indicators appear to provide useful information about the risk of cumulative effects of watershed disturbance, and this information can be delivered consistently and quickly (Collins and Pess 1997; Carver 2001; Chatwin 2001).

IWAP indices used in the original Level 1 procedure (BCF and BCE 1995b) are summarized in Table 17; reference to their status in the 'Revised IWAP' is also included. They are described in more detail below.

Table 17. British Columbia Interior Watershed Assessment Procedure indicators and thresholds.

Indicator	Guideline or Threshold	Comments
IWAP Peak Flow Hazard	Peak flow index greater than 0.18 km/km^2 indicates risk of cumulative effect.	Index represents Equivalent Clearcut Area calculated by sub-basin. H_{60} weighted in Revised IWAP.
	Road density greater than 0.3 km/km^2 above H_{60} line indicates risk of cumulative effect.	H_{60} represents the upper 60% of a watershed based on area-elevation curve. Dropped from Revised IWAP.
	Road density greater than 0.9 km/km^2 for entire sub-basin indicates risk of cumulative effect.	Road and trail network based on TRIM base map or Forest Cover Block maps.
	% of watershed cleared.	Added in Revised IWAP.
IWAP Erosion Hazard	Riparian roads: riparian road density greater than 0.12 km/km^2 indicates risk of cumulative effect.	Riparian roads classified as those <100 m from a stream calculated by sub-basin. Dropped from Revised IWAP.
	Riparian road density greater than 0.06 km/km^2 on erodible soils indicates risk of cumulative effect.	Dropped from Revised IWAP.
	Stream crossings: stream crossings by roads greater than 0.24/km^2 indicates risk of cumulative effect.	Stream crossing number calculated by sub-basin. Dropped from Revised IWAP, but used elsewhere.
	Road density greater than 0.9 km/km^2 for entire sub-basin indicates risk of cumulative effect.	
	Road density greater than 0.06 km/km^2 on erodible soils indicates risk of cumulative effect.	Erodible soils defined using available soils maps and reports or based on slope and soil attributes.
IWAP Riparian Hazard	Riparian area cleared: greater than 0.09 km/km of streambank cleared indicates risk of cumulative effect.	Riparian zone assumed to be within 100 m of streams. Dropped from Revised IWAP.
	Riparian area cleared: greater than 0.15 km/km of fish-bearing streambank cleared indicates risk of cumulative effect.	Fish-bearing streams as defined in Forest Practices Code guidebooks. Replaced with S1/S2/S3/S4 streams in Revised IWAP.
IWAP Landslide Hazard	Greater than 0.06 landslides/km^2 indicates risk of cumulative effect.	Number of landslides calculated by sub-basin.
	Road density greater than 0.09 km/km^2 on unstable slopes indicates risk of cumulative effect.	Unstable slopes as defined in Forest Practices Code guidebooks.
	Riparian area cleared: greater than 0.09 km/km of streambank cleared on slopes >60% indicates risk of cumulative effect.	Riparian clearing on steep slopes calculated by sub-basin. Dropped from Revised IWAP.

5.5.1 Equivalent Clearcut Area

The Equivalent Clearcut Area index (ECA) was one of the earliest cumulative watershed effects indicators and was developed by the US Forest Service. This index was developed to evaluate the effect of forest harvest on stream channel conditions. It assumes that peak stream flows (and basin water yield) increase as a result of increased snow accumulation and reduced evapotranspiration due to forest clearing. Because most hydrologic impacts occur during periods of peak stream flow in a watershed, ECA provides an indicator of potential watershed impact. This index does not consider other sources of cumulative effect such as sediment input or persistent physical features such as landslides (e.g., Troendle and King 1985; Reid 1993; BCF 1999).

ECA calculations include all areas that have been harvested, cleared, or burned with factors applied to account for hydrological recovery due to forest regrowth, regeneration, or harvest system. In British Columbia, second growth is considered to be recovered when snowpack conditions approximate those prior to clearing (BCF and BCE 1995b).

Application of ECA models requires calibration to relate increases in water yield to vegetation type, elevation, and age of activity. Water yield values for each land type and disturbance feature are then compared to water yield values for a clearcut. The area of clearcut that would produce the same change (the 'equivalent clearcut area') is then calculated. This is used to calculate the ECA coefficients for each disturbance feature. The amount of monitoring required for full coefficient calibration is usually prohibitive, so professional judgement is often used to define ECA coefficients (Reid 1993).

In the United States, where most forestry-related watershed studies have been done, harvesting has been found to increase annual water yield by 100 to 500 mm per year; increases are inversely related to mean annual precipitation (Bosch and Hewlett 1982; Troendle and King 1985; BCF and BCE 1995b; Jones and Grant 1996; Burton 1997). Research has also shown post-clearing increases in water yield in the British Columbia interior and Alberta Rockies, but increases are less than those reported in United States studies (Nip 1991; BCF and BCE 1995b) and are highly variable (Scherer 2001). This is at least partly due to the snowfall-dominated hydrological regime in western Canada; most runoff occurs during a comparatively brief period of spring snowmelt (BCF and BCE 1995b; Scherer 2001).

Calculation of ECA requires information on the date, area, and type of clearings or disturbed areas and the length of roads, trails, and other linear corridors. The predictive power of the ECA index appears to be weak (Reid 1993; Carver 2001; Scherer 2001). However, when its limitations are acknowledged, it can help identify watersheds with an increased risk of cumulative effects. ECA hazard levels for ECA assigned in the original IWAP rating scheme (BCF and BCE 1995b) were:

- **Low**: 0 to 18% ECA,
- **Medium**: 18 to 36% ECA, and
- **High**: >36% ECA.

5.5.2 Riparian Area Cleared/Disturbed

Riparian areas include the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize stream banks, regulate stream temperature, and provide a continuous source of woody debris, nutrients, and food organisms (BCF 1999). Clearing of riparian areas can lead to increased bank erosion, altered stream channel dimensions, lowered groundwater table and summer flows, increased summer temperatures, and winter icing (Armour et al. 1994; BCF and BCE 1995b). Riparian habitat can also be altered by deliberate or inadvertent introduction of non-native or exotic vegetation that alters substrate, banks, or trophic relationships.

Riparian area conditions have been used as indicators of both cumulative land use and waterbody integrity. Riparian habitat conditions appear to influence aquatic (and terrestrial) species presence, distribution, and abundance at both local and watershed scales (e.g., Platts 1991; Waters 1995; Roth et al. 1996; Jones et al. 1999). In agricultural areas, riparian habitat conditions were found to be the best predictors of sediment-related habitat variables (Richards et al. 1996) and stream ecological integrity (Roth et al. 1996).

A frequently overlooked source of riparian habitat loss is stream crossings (Garant et al. 1997; Brown 1999). A recent study in the Prince George Forest District found that an average of 0.06 ha of riparian habitat was lost at each road crossing (Harper and Quigley 2000). In the Alberta foothills, linear corridors generally affect 2% to 5% of riparian areas, and are normally the largest source of riparian clearings (Salmo unpub. data). Forest harvest is no longer allowed in the riparian management zone in northeast British Columbia, so the incremental effects of linear corridors will continue to increase.

Hazard levels for riparian clearing assigned in the original IWAP rating scheme (BCF and BCE 1995b) were:

- **Low**: 0 to 9%,
- **Medium**: >9 to 18%, and
- **High**: >18%.

5.5.3 Road Density

Roads can directly and indirectly create all the cumulative effects described in Section 2.3 (Reid 1993; Trombulak and Frissell 2000). Road density appears to be one of the most useful watershed cumulative effects indicators for aquatic systems as well as terrestrial systems (BCF 1999; Bauer and Ralph 2001; Carver 2001). Aquatic road density guidelines and thresholds were summarized in Table 14.

On average, roads in southeast British Columbia watersheds contributed 24% of the total annual sediment yield (Henderson and Toews 2001; Jordan 2001); roads in the Alberta foothills were the largest source of sediments from human activities (Anderson and Anderson 1987). As with terrestrial habitat, the response of any particular stream is contingent to some degree on local conditions (MBTSG 1998). As a result, road density does not appear to provide reliable predictions of sediment yield (Henderson and Toews 2001).

Hazard levels for road density (calculated for entire subwatersheds) assigned in the original IWAP rating scheme (BCF and BCE 1995b) were:

- **Low**: 0 to 0.9 km/km^2,
- **Medium**: 0.9 to 1.72 km/km^2, and
- **High**: >1.72 km/km^2.

In general, observed or derived road density thresholds for fish and aquatic environments are higher than those for terrestrial species or habitat. This likely reflects the indirect link between upland roads and watercourses.

5.5.4 Equivalent Roaded Area

Equivalent roaded area (ERA) is another watershed disturbance index developed by the US Forest Service. This index assumes that peak stream flows (and basin water yield) increase as a result of compaction and reduced infiltration from road networks. By converting all land use activities to an ERA index, disturbances throughout a watershed can be considered. ERA calculations are similar to those described for ECA, but the method is customized to address issues relevant to each management area (Reid 1993; McGurk and Fong 1995).

ERA provides a screening tool to identify watershed with increased risk of cumulative effects, rather than to predict effects. ERAs are likely to be grossly correlated with many types of impacts (Reid 1993).

McGurk and Fong (1995) detected no effect on benthic communities when ERA was <5% of a subwatershed, but ERAs above this threshold were associated with a decline in macroinvertebrate density and an increase in dominance of the top five taxa.

5.5.5 Riparian Roads

The concept of roads within 100 m of a watercourse (riparian roads) was introduced in the IWAP as an index of surface erosion potential. The two most important factors in determining how much fine sediment will be delivered to watercourses from roads are the proximity of the road to the stream and the parent material the road was built on. The riparian road indicator attempts to quantify this hazard (BCF and BCE 1995b).

Many roads and trails follow valley plains and floodplains of watercourses, since the soil conditions and level terrain in these areas make construction relatively easy and economical. Roads in proximity to watercourses or those within the riparian zone can cause streambank destabilization, increased surface erosion and sedimentation, dewatered channels, obstruction to fish passage, and altered channel locations (BCF and BCE 1995b; Harper and Quigley 2000).

Hazard levels for riparian roads assigned in the original IWAP rating scheme (BCF and BCE 1995b) were:

- **Low**: 0 to 0.12 km/km^2,
- **Medium**: >0.12 to 0.25 km/km^2, and
- **High**: >0.25 km/km^2.

5.5.6 Stream Crossings

The number of road crossings of streams has been used as an indicator of land use activity for aquatic evaluations (Baxter et al. 1999; BCF 1999). This index is an easily calculated measure of sediment and mortality sources and stream habitat fragmentation in a watershed. It is expressed as the number of access corridor (road, trail, utility corridor, or cutline) crossings per kilometre of stream or watershed area. A watercourse that is repeatedly crossed is more likely to suffer increased erosion and water temperature, have higher angling pressure, and have temporary or permanent barriers to fish passage. Stream crossing indices can be calculated independently for each linear feature or similar features can be combined; an example was provided in Table 15.

Active stream crossings are often a chronic source of sediments and in-stream and riparian habitat changes. This can be either directly from the crossing construction, or indirectly from delivery of sediments along the right-of-way (Reid and Dunne 1984; BCF and BCE 1995b; Anderson 1996; Haskins and Mayhood 1997; Anderson et al.1996, 1998; Brown 1999; Reid and Anderson 1999). Road stream crossing density was positively correlated with fine substrate and embeddedness and negatively correlated with trout standing stocks in a foothills area of Wyoming (Eaglin and Hubert 1993).

Stream crossings also represent points of access for subsistence users and anglers as well as potential barriers to movement. An inventory of road crossings in the Prince George Forest District of British Columbia found that 36% of surveyed road culverts were barriers to movement (Harper and Quigley 2000). A similar study in the Alberta foothills near Edson found that 29% of surveyed road culverts were probable barriers to movement, and 40% were possible barriers (Marshall 1996).

Bull trout redd densities and counts were inversely correlated with the number of road crossings per catchment in the Swan River drainage of northern Montana (Baxter et al. 1999). As with terrestrial habitat fragmentation, actual effects depend on the extent and nature of the disturbance, watershed geology and topography, and species present, among others.

The stream crossing index provides the most direct indicator of cumulative effects erosion and mortality risk because it only includes features that intersect watercourses.

6. SPECIES-SPECIFIC INDICATORS AND THRESHOLDS

Appropriate species or guilds used for cumulative effects assessment and management are generally selected by considering the following criteria (adapted from Noss 1990):

- economic importance (e.g., **featured** species important for hunting, fishing, traditional land use, or recreation),
- sensitivity to potential development activities or early indicator of environmental stress or incremental demand on facilities and services (e.g., **ecological** and **sensitive** indicators: species that signal the effects of perturbations on a number of species with similar habitat requirements),
- importance in the food chain or ecosystem function (e.g., **keystones**: pivotal species upon which the diversity of a large part of a community depends),
- social importance (e.g., **flagships**: popular, charismatic species that serve as symbols and rallying points for conservation initiatives),
- special conservation status (e.g., **vulnerables**: species that are rare, genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise vulnerable to extinction in human-dominated landscapes),
- ecological or economic significance for more than one discipline and disturbance type (e.g., **umbrellas**: species with large area requirements that incorporate many other species),
- ability to be quickly and cost-effectively calculated, estimated or assessed from existing data sources, and
- ability to be efficiently and cost-effectively monitored.

In British Columbia, the Identified Wildlife Management Strategy (BCF and MELP 1999a) was established under the Forest Practices Code to help conserve biodiversity. 'Identified Wildlife' are legally-designated species or plant communities that are considered to be at risk and require special management of critical habitats in order to maintain or restore populations or distributions. These critical habitats include breeding, denning, or feeding sites.

Summaries of indicators and thresholds are provided for the following focus species found in northeast British Columbia:

- bull trout (*Salvelinus confluentus*),
- grizzly bear (*Ursus arctos*), and
- woodland caribou (*Rangifer tarandus*).

6.1.1 Bull Trout

Bull trout are a char native to foothills streams of British Columbia, including the Peace and Liard River drainages. Although the species is widely distributed in the region, and is not in danger of extinction, bull trout are Blue-listed because populations are declining throughout its global range. In British Columbia, the declines are mainly due to habitat degradation, disruption of migration patterns, and overfishing (MELP 1997). Bull trout are also classified as an Identified Wildlife Species (BCF and MELP 1999a).

Spawning generally occurs in late August to late September in small streams with groundwater inflow. Three ecotypes are recognized based on movement and residence patterns. Stream **resident** populations spend their entire lives in headwater streams and overwinter in deep pools. Juveniles of **fluvial** populations remain in their natal stream or other small streams for one to five years after emergence. Fluvial adults spend most of their lives in larger rivers and migrate into smaller tributaries during summer to feed and spawn; they return downstream immediately after spawning to overwinter in deep pools and mainstem rivers such as the Peace and Fort Nelson. **Adfluvial** populations reside in lakes but use tributaries for spawning and juvenile rearing.

Bull trout are considered to be a suitable cumulative effects indicator species because of their importance for recreational fishing (flagship), they are fall-spawning predators associated with low productivity waterbodies (ecological), fluvial forms utilize a variety of habitats in different environments (umbrella), they are sensitive to overharvest, competition, and hybridization (vulnerable), and are reliant on localized spawning habitat (sensitive; Fraley et al. 1989; Weaver and Fraley 1991; Rieman and McIntyre 1993; MELP 1997; Salmo 2000).

Bull trout have lower ecological resilience than many other fish species in the region. They appear to have a narrower range of habitat preferences than other salmonids, and are uncommon where temperatures exceed 15°C. Fluvial and adfluvial populations are often late maturing, and must survive for at least five years before spawning for the first time; this reduces reproductive productivity. Bull trout spawning areas are very restricted and localized; this makes them very sensitive to effects of altered groundwater flow, siltation, erosion, and removal of instream cover. Fluvial adults generally migrate long distances (up to 200 km) to spawning and poorly installed culverts or other barriers can restrict access to spawning areas. After migrating, virtually all adults in a run congregate in a single staging area (usually a pool) prior to spawning; at this time, mature adults can be easily harvested. Incubating eggs require stable, high quality water flow for a prolonged winter period. Finally, young-of-the-year and yearling bull trout may successfully overwinter in relatively small tributary streams where they often survive despite marginal discharge and apparent lack of flow. These small watercourses have high potential to be affected by human disturbance (Fraley et al. 1989; Ford et al. 1995; MELP 1997).

Cumulative effects guidelines and thresholds applicable to bull trout are summarized in Table 18. Most quantitative evaluations on this species have been conducted in the

United States near the southern limit of their range where bull trout are considered to be at risk (e.g., Rieman et al. 1997; MBTSG 1998).

Table 18. Indicators and guidelines relevant to bull trout.

Indicator	Guideline or Threshold	Comments
Disturbance Buffer	• Identified wildlife buffers Bull trout = 500 m on each side of stream (BCF and MELP 1999a).	• Recommended British Columbia buffers.
Road Density	• Watersheds with >1 km/km^2 road density had degraded bull trout habitat (Craig 2001).	• Based on studies in Yakima River basin, Washington.
	• Road density <1.5 km/km^2 to protect bull trout (BCF and MELP 1999a).	• Recommended British Columbia threshold; additional site-specific work required beyond this point.
	• Bull trout populations were seven times more likely to be strong in subwatersheds with road densities <1.55 km/km^2 (Rieman et al. 1997).	• Based on study in interior watersheds in Pacific Northwest United States.
	• Watershed road densities >2.5 km/km^2 increased sediment yield and affected downstream salmonid spawning habitat (Cederholm et al. 1981).	• Based on study in coastal watershed in Pacific Northwest United States.
	• 0 to 0.9 km/km^2 Low; 0.6 to 1.72 km/km^2 Medium; >1.72 km/km^2 High Aquatic Hazard (BCF and BCE 1995b).	• Aquatic hazard rating developed for British Columbia.
Stream Crossing Index	• >0.4 stream crossings by roads per km^2 indicates risk of cumulative effects (BCF and BCE 1995b).	• Part of IWAP procedure; calculated by subwatershed.
	• <0.6 stream crossings by roads per km^2 indicates risk of cumulative effects (BCF and MELP 1999a).	• Recommended British Columbia thresholds; additional site-specific work required beyond this point.
Substrate Index	• <40% median fine sediment (<6.4 mm) in substrate of bull trout spawning areas (Enk 1992; Weaver and Fraley 1991).	• Management threshold for Flathead River basin, Montana.

No studies exist that document in detail the linkages between land use and the biological responses of a specific bull trout population. The natural variability and complexity of abiotic and biotic factors means that a cause-effect model that relates human disturbance to bull trout populations throughout their range is unlikely to be developed. However, several comparative watershed or landscape studies have demonstrated some predictability or pattern in the status of bull trout populations relative to gross land use or watershed indicators. Although local conditions are known to be important, this likely reflects general patterns in watershed biophysical processes (Roth et al. 1996; Watson and Hillman 1997; MBTSG 1998).

A long-term study conducted in the Flathead River basin of northern Montana provides information on the effects of road construction and forest harvest on bull trout habitat and abundance. Investigators found that juvenile bull trout densities and redd counts were inversely correlated to a streambed condition index (% of sediments <6.4 mm; Shepard et al. 1984; Weaver and White 1985). These substrate indices were correlated with estimated sediment loads from road development (Enk 1984; Shepard et al. 1984; Leathe and Enk 1985) and were inversely related to embryo survival (Shepard et al. 1984; Weaver and White 1985; Weaver and Fraley 1991). Between 1982 and 1995, bull trout redd counts were inversely correlated with road density and the number of road crossings in spawning tributary watersheds (Baxter et al. 1999). Redd density appeared to be most strongly linked to road densities for the previous 7 to 12 years, suggesting a lag time of a decade or more between road construction and the full expression of its effects on bull trout spawning populations (MBTSG 1998; Baxter et al. 1999). A sediment condition index was developed for watershed management in this area (Enk 1992).

In the Columbia River basin, road density was also inversely correlated with aquatic habitat conditions, aquatic habitat integrity, known bull trout spawning areas, and bull trout presence (Henjum et al. 1994; Lee et al. 1997 *in* MBTSG 1998; Rieman et al. 1997).

6.1.2 Grizzly Bear

The grizzly bear is widely used as an umbrella species for the assessment and management of cumulative effects at regional scales (Noss et al. 1996; Kansas 2002). Grizzly bear are Blue-listed in British Columbia, classed as Special Concern by COSEWIC (2002), and are classified as an Identified Wildlife Species (BCF and MELP 1999a). Estimated grizzly bear numbers are below historic and current potential in northeast British Columbia and have been extirpated from the Peace River lowlands, local populations elsewhere in the region are not considered to be at risk (Cannings et al. 1999; Culling and Culling 2001).

Grizzly bears are considered to have low ecological resilience (Weaver et al. 1996) and display variable life history and home range sizes. Distinct seasonal habitat use periods occur during spring, summer and fall. Female home ranges are usually smaller than males and females with young appear to select isolated habitats; this is thought to minimize disturbance and encounters with mature males that kill cubs. Reproductive rate is the lowest recorded among North American land mammals. Subadult female dispersal outside maternal home ranges is rare in much of British Columbia, so areas where all resident adult females have been killed are usually not recolonized (reviewed in MELP 1995, 1997; Cannings et al. 1999; Culling and Culling 2001).

Development of cumulative effects assessment methods for grizzly bear began in the early 1980's and are now well established and generally accepted (Gibeau et al. 1996; Kansas 2002). The standardized Cumulative Effects Model (CEM; Weaver et al. 1986; USDA 1990) includes three components: habitat effectiveness (integrating habitat availability, quality, and disturbance); mortality; and connectivity (linkage zone prediction). Conventional Canadian grizzly bear cumulative effects assessment methods are described in Apps (1993), Gibeau et al. (1996), ESGBP (1998), and Kansas (2002) and will not be discussed further. Each component is applicable at different scales and for different cumulative effects pathways; they are most frequently used as a suite (Axys 2001a).

Recommended and established habitat guidelines for grizzly bear are summarized in Table 19.

6.1.2.1 Habitat Effectiveness

There is considerable evidence that grizzly bears avoid occupied and active human facilities (reviewed in Mattson 1993). The reported Zone of Influence (ZOI) varies by geographic setting, season and time of day, type of use (motorized or non-motorized; dispersed or point source), and intensity and frequency of use, among others (e.g., Archibald et al. 1987; McLellan and Shackleton 1988, 1989; Kasworm and Manley 1990; Manley and Mace 1992; Mace and Manley 1993; Mace et al. 1996; Gibeau 2000).

Habitat effectiveness models were discussed in Section 4.1.2. Grizzly bear cumulative effects assessments in western Canada have adopted a standardized 500 m ZOI (Axys 2001a), or the ZOI originally developed for the Yellowstone Ecosystem: 800 m ZOI for motorized access roads, and 400 m for non-motorized trails and corridors (e.g., Gibeau et al. 1996; ESGBP 1998).

Habitat effectiveness evaluations appear to be useful for comparing the relative amounts of effective habitat loss between subregional planning units, but the relationship between these numerical values and actual grizzly bear use or density is more tenuous. In studies west of Calgary, the lowest levels of habitat effectiveness (49% to 65%) were reported in areas where most resident grizzly bears occurred. Conversely, grizzly bears were much less common in areas with high habitat effectiveness values (76% to 82%; Kansas 2002).

Core area evaluation was discussed in Section 4.1.4; this technique was originally developed for grizzly bears

Table 19. Habitat indicators and guidelines for grizzly bear.

Indicator	Guideline or Threshold	Comments
Habitat Availability	▪ <10% of each Forest Operating Unit should be affected by logging (Horejsi 1996).	▪ Recommendation to protect grizzly bear in Yukon Territory.

Table 19. Habitat indicators and guidelines for grizzly bear (cont.).

Indicator	Guideline or Threshold	Comments
Habitat Effectiveness	No net loss of habitat effectiveness for grizzly bear (BCF and MELP 1999a).	Recommended British Columbia threshold.
	Resident female range use appears to be severely restricted in areas with <50% habitat effectiveness (Kansas et al. 1997; Gibeau et al. 1996; ESGBP 1998; Kansas 2002).	Based on studies in Banff Park and Kananaskis Country west of Calgary.
	Most areas with resident female grizzly bears have habitat effectiveness >70% (Parks Canada 1997).	Based on study in Jasper National Park.
	>80% of all Bear Management Units with 80% or greater habitat effectiveness for grizzly bear (Parks Canada 1997).	Threshold adopted by Banff National Park.
	>80% habitat effectiveness for grizzly bear (Horejsi 1996).	Recommendation calculated based on road density, assuming that 1 km/km^2 equates to 80% habitat effectiveness.
Edge Use	Grizzly bear consistently under-use habitat within 500 m of high use roads; most grizzly bear mortality occurs within 500 m of roads and facilities and 200 m of backcountry facilities and trails (Mattson 1993; Gibeau et al. 1996; Mace et al. 1996; ESGBP 1998).	Based on work in Banff National Park, Montana, and Greater Yellowstone Ecosystem.
Core Area	Minimize loss of core habitat (NCGBRT 2001).	Recommendation for recovery of grizzly bear in the North Cascades of B.C.
	No Net Loss of Core Area for grizzly bear (NCGBRT 2001).	Grizzly bear management goal in the North Cascades of Washington.
	>60% of available habitat as core area (Gibeau 2000).	Grizzly bear management threshold for Banff National Park.
	>58 to 68% of land area as core areas (NCGBRT 2001).	Management goal for grizzly bear in Montana and Idaho National Forests.
	>60% of Forest Planning Area as roadless core wildlife habitat (Horejsi 1996).	Grizzly bear management recommendation for Yukon Territory.
Suitable Core Area	Minimum viable core area of 450 to 1,000 ha (Gibeau et al. 1996).	Grizzly bear core area used in western Canadian analyses based on 24 to 48 hr. feeding bout of an adult female grizzly.
	Core area >10 ha in size, ideally >1,000 ha (NCGBRT 2001).	Recommendation for recovery of grizzly bear in the North Cascades of B.C.
	No vegetation change within established grizzly bear core areas for at least 11 years (USFS 1993).	Management goal for Idaho National Forest.
	Total weighted road density should be 0 km/km^2 in grizzly bear core areas (USFS 1993).	Management goal for Idaho Nat'l Forest; Total Weighted Road density considers hiding cover, use intensity, and closure status to provide a common standard.

Habitat effectiveness and core area evaluation must also be put into regional context. Effects on grizzly bears are different on forested public lands of northeastern British Columbia than in highly fragmented habitats in more densely populated areas. Human use and pressure in this region is much lower than many areas of southern British Columbia, Alberta, and the northwest United States where grizzly bears must coexist with large numbers of people and where most quantitative studies have been conducted (Servheen 1993; Culling and Culling 2001).

6.1.2.2 Road Density

Recommended and established land use guidelines for grizzly bear are summarized in Table 20. Road density standards have become an important component of grizzly bear management (Mattson 1993; Dugas and Stenhouse 2000). Road density thresholds have also been proposed for British Columbia (BCF and MELP 1999a).

In northern Montana, grizzly bear research found that most grizzlies exhibited a neutral or positive response to roads receiving less than 10 vehicles per day (300 per month), but avoided roads with higher traffic volumes. Grizzly bears can persist in areas with roads, but spatial avoidance increases and survival decreases as traffic levels, road densities, and human settlement increase. Average total road density was 0.6 km/km^2 in areas used by female bears as compared to 1.1 km/km^2 outside the composite home range. In this analysis, total road density included roads open and closed to vehicle traffic, but excluded old roads reclaimed by natural vegetation or roads in timber harvest units (Mace et al. 1996). In southeast British Columbia, grizzly bears selected lower elevation riparian areas with average road density of 0.68 km/km^2 during spring and fall (McLellan and Hovey 2001). Mace et al. (1996) frequently found grizzly bears in regenerating cutblocks but these features were consistently selected less than other habitats in the Flathead valley (McLellan and Hovey 2001).

Table 20. Land use and mortality indicators and guidelines for grizzly bear.

Indicator	Guideline or Threshold	Comments
Road Density	▪ Road density <0.6 km/km^2 to protect high quality grizzly bear habitat (BCF and MELP 1999a).	▪ Recommended British Columbia threshold.
	▪ Areas selected by grizzly bears had average road densities of 0.6 to 0.68 km/km^2 (Mace et al. 1996; McLellan and Hovey 2001).	▪ Based on studies in northern Montana and southeast British Columbia.
	▪ Areas with road densities greater than 6 km/km^2 do not support grizzly bears (Mace et al. 1996).	▪ Based on study in northern Montana.
	▪ Forest Operating Area with road density >1.25 km/km^2 on <10% of area and additional 10% up to 0.6 km/km^2 (Horejsi 1996).	▪ Management recommendation for grizzly bear in Yukon Territory.
	▪ <30% of Forest Operating Area with road density <0.3 km/km^2 (Horejsi 1996).	▪ Management recommendation for grizzly bear in Yukon Territory.

Table 20. Land use and mortality indicators and guidelines for grizzly bear (cont'd).

Open Road Density	- Average open road density <0.45, <0.48, or <0.6 km/km^2 (Servheen 1993).	- Management objectives in Yellowstone Grizzly Bear Recovery Zone National Forests.
Mortality	- <4% grizzly bear harvest rate from all sources; females should be <33% of total kills, including estimated natural mortality, accidental kills, and illegal kills (MELP 1995).	- Sustainable harvest rate for British Columbia.

Differences in response of grizzly bears may reflect the amount of use that roads receive. In southeast British Columbia, high grizzly bear densities occurred in areas with higher open road densities than observed in American studies (McLellan 1990; Servheen 1993). However, these roads receive very little use except during hunting season, while use is much higher in most areas of Montana, Idaho, Wyoming, and Washington with comparable road densities. Proximity to human population centres, ease of access, and actual road use intensity are therefore important factors (Servheen 1993). Studies in relatively unpopulated areas of the Alberta foothills indicate that human use of cutlines, utility corridors, and trails is generally lower than previously thought, and that most would be classified as 'no-use' features for grizzly bear habitat effectiveness purposes (Kansas and Collister 1999; Salmo unpub. data).

Ideally, grizzly bear road density standards should vary as a function of bear home range and human dimensions (e.g., population density and attitudes towards bears). They should reflect mortality risk more than habitat alienation, and allow the effects of vegetation cover, topography, and road closures to be considered. Studies to confirm cause-effect relationships between road density and grizzly bear populations should include an area equivalent to approximately 10 female home ranges, including areas not impacted by roads (Mattson 1993).

6.1.2.3 Mortality

Direct and indirect human-cause mortality appears to be the most significant factor affecting grizzly bear populations in western North America (Mattson 1993: ESGBP, 1998; McLellan et al. 1999).

Human-caused grizzly bear mortality is determined by the rate of encounter between humans and bears and by the probability that such an encounter will result in a bear's death. Encounter and mortality rates are affected by human population density and access patterns, human and bear behaviour during and following an encounter, grizzly bear population density and social structure, and the distribution of bear foods (reviewed in Mattson et al. 1996). Most grizzly bear mortality occurs within 500 m of roads and facilities and 200 m of backcountry facilities and trails (Mattson 1993; Gibeau et al. 1996; Mace et al. 1996; ESGBP 1998).

Because of their low productivity, grizzly bear populations respond slowly to impacts that produce a change in status. In British Columbia, maximum sustainable harvest has been set at 4% of the estimated population, including kills from all sources. The unreported kill from natural mortality and accidental and illegal kills is standardized at 50% of the total kill unless documentation indicates otherwise. Total harvest should include no greater than 33% females, and hunting seasons are not permitted in management units with fewer than 26 bears. Between 1984 and 1993, sustainable harvest rates were frequently exceeded in the province (MELP 1995; Table 20).

Human dimensions must be factored with changes in access to evaluate the effect of access management on grizzly bear mortality. Access reduction promises the greatest gains where people are unarmed visitors. In areas where people are armed and hostile towards bears, there may be no gains (or even increased mortality) by restricting access unless road closures are totally effective (Mattson et al. 1996).

6.1.2.4 Connectivity

Linkage zone prediction considers the degree of landscape fragmentation caused by human disturbance and identifies areas where grizzly bear movements are not adversely impacted. This is used to identify and protect critical movement corridors between important seasonal habitats, or to identify barriers to movement (Servheen and Sandstrom 1993; Gibeau et al. 1996). In Banff National Park, the busy Trans-Canada Highway appears to create a barrier to female grizzly bear movements. Male bear highway crossings occur more frequently, but this high use linear corridor could have profound effects on bear habitat use and movements in the Bow River valley (Gibeau and Heuer 1996).

Connectivity models are most applicable in highly fragmented landscapes or narrow valleys where movements are restricted by topographic features. They have not been tested for validity (Salmo et al. 2001).

6.1.3 Woodland Caribou

Two woodland caribou ecotypes are present in northeast British Columbia, 'northern' and 'boreal' (Heard and Vagt 1998). Most individuals of the 'northern-ecotype' spend the spring, summer and fall in subalpine spruce/balsam (*Picea/Populus* spp.) and lodgepole pine forests and alpine tundra. During winter, they use a combination of windswept alpine and low- to high-elevation mature to old coniferous forests where lichens are most abundant and available. Considerable individual and between-year variability in habitat use is observed. Some individuals remain in low elevation coniferous BWBS forests year-round. Deciduous and mixedwood forests appear to be avoided (Edmonds and Bloomfield 1984; Sopuck 1985; Murray 1992; Backmeyer 1994; Brown and Hobson 1998; Apps et al. 2001, Culling and Culling 2001).

'Boreal-ecotype' caribou reside in low elevation coniferous forests year-round. Treed fens and bogs appear to be important Black spruce forest and their distribution may overlap with northern-ecotype caribou during winter (Bradshaw et al. 1995; Stuart-Smith et al. 1997; Brown and Hobson 1998; Anderson et al. 1999, Rettie and Messier 2000).

Caribou have a relatively low productive rate. Females are generally 2.5 years old before first breeding, and rarely produce more than one calf per year. The most important source of adult caribou mortality is predation by wolves, followed by predation by bears, and legal and illegal hunting (Bergerud and Elliot 1998; Dyer 1999; reviewed in Culling and Culling 2001).

Relative safety from predators is assumed to be a key feature of habitat used by caribou. Woodland caribou are assumed to reduce the risk of predation by using habitat that separates them from other ungulates and existing at low densities over large ranges so that encounters with predators are minimized (Bergerud and Page 1987). A recent study in north-central Alberta found that boreal-ecotype caribou used areas adjacent to wellsites and linear corridors less than expected, presumably to reduce the risk of predation (Dyer 1999; James and Stuart-Smith 2000).

Access creation can increase hunting and predation rates by providing travel corridors that allow humans and wolves to increase their encounter rate and hunting efficiency (Bergerud et al. 1984; Cumming and Beange 1993; James 1999). In north-central Alberta, predation rates for caribou were higher in proximity to linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000). In the west central Alberta foothills, however, non-forested clearings and linear corridors were least preferred by wolves (Kuzyk 2002). Clearing and access creation may alter caribou movements and distribution and also lead to increased predation and hunting pressure (Whitten et al. 1992; James and Stuart-Smith 2000; Dzus 2001).

Between 1960 and 1980, a precipitous decline of woodland caribou populations occurred in western Alberta (Bloomfield 1979; Dzus 2001), southern British Columbia (Harding and McCullum 1994), and northeast British Columbia (Harper 1988). In all areas, this decline occurred concurrently with an increase in road access and logging that is believed to have significantly increased mortality from hunters and wolves (Bergerud et al. 1984; Seip 1992; Harding and McCullum 1994). This is considered to be a good example of the cumulative effects of human development and habitat fragmentation (Harding and McCullum 1994).

Northern-ecotype caribou populations in northeast British Columbia are believed to have declined significantly in the past decade (Culling and Culling 2001). Fewer data are available for boreal-ecotype caribou, but monitored populations in Alberta have exhibited substantial declines over the last 4 to 9 years (Dzus 2001; BCC 2002).

No specific models relationships have been developed to relate access density to woodland caribou habitat effectiveness. Nellemann and Cameron (1998) found that the density of calving barren-ground caribou was inversely related to road density although non-maternal individuals did not display the same relationship (Dau and Cameron 1986). Vehicle traffic influenced barren-ground caribou crossing success more than the presence of elevated pipelines and roads (Murphy 1984).

Boreal-ecotype caribou in boreal habitat in north-central Alberta used areas near wells, roads and cutlines less frequently than expected (Dyer 1999; Table 21). Caribou in the nearby Redrock/Prairie Creek range of the west central Alberta foothills used areas within 500 m of active roads and 250 m of inactive roads and streams less frequently than expected during winter, but use of areas within 100 m of cutlines did not differ from that expected (Oberg 2001). Caribou in this range also used areas within 540 m of old cutblocks and 1.2 km of newly harvested cutblocks less frequently than expected (Smith et al. 2000). Research will be required to determine actual response of boreal- and northern-ecotype caribou in northeast British Columbia.

Table 21: Caribou reduced use buffers in north-central Alberta (Dyer 1999).

SEASON	FEATURE				
	ROADS		WELLSITES		
	Open Coniferous Wetland	Closed Coniferous Wetland	New - <15.5 months old (drilling completion date)	Old - ≥15.5 months old (drilling completion date)	Seismic Lines
Early Winter Nov 16 - Feb 21	*	*	250 m	0 m	100 m
Late Winter Feb 22 - Apr 30	250 m	250 m	250 m	500 m	250 m
Calving May 1 - Jun 30	100-250 m	0 m	1000 m	500 m	100 m
Summer July 1 - Sep 15	250 m	100 m	0 m	250 m	100 m
Rut Sep 16 - Nov 15	250 m	0 m	250 m	0 m	100 m

* Insufficient caribou had roads within their home ranges to perform analysis to examine avoidance of roads during this time period.

Current average corridor densities in the winter range of the Little Smoky boreal-ecotype herd are 0.23 km/km^2 for roads, 0.77 for truck trails, 0.15 km/km^2 for utility corridors (pipelines), and 2.90 km/km^2 for cutlines. Existing road and truck trail corridor densities are calculated to be Very Low or Low (<0.4 km/km^2) on about 35% of the Little Smoky caribou winter range and Moderate on approximately 28% of the area. High to Extremely High access densities are present on approximately 37% of the caribou winter range (Salmo unpub. data). This population is declining (Brown and Hobson 1998).

Based on information provided in Brown and Hobson (1998) and Smith et al. (2000), the main wintering areas of the nearby Redrock/Prairie Creek northern-ecotype caribou herd are located in subwatersheds with access densities between 0.35 and 0.6 km/km^2, and this herd appears to have at least temporarily moved away from areas with road and trail densities that exceed 0.6 km/km^2 (Salmo unpub. data). On this basis, an average road and trail density threshold of 0.6 km/km^2 was derived for northern- and boreal-ecotype caribou in west central Alberta (Salmo unpub. data).

Caribou in the Little Smoky herd have relatively large winter home ranges that average 14,700 ha (Edmonds and Bloomfield 1984). The most critical factor appears to be availability of suitable habitat during late winter when movements become restricted (Edmonds and Bloomfield 1984).

In the Graham River area, all but one radio-collared animal were considered to be migratory and moved more than 15 km between summer and winter ranges. Average annual home range size was 543 km^2 (range 161 to 963) and average migration distance between seasonal home ranges was 41.4 km. All caribou that wintered in low elevation BWBS forest returned to the alpine and subalpine habitats by early June (Backmeyer 1994).

No specific thresholds for core area were located for woodland caribou, however this concept was originally applied to grizzly bears and work on that species is applicable. Like caribou, female grizzly bears appear to require a portion of their home range that is secure from disturbance and mortality associated with high use human features. These core security areas are considered to be that portion of home range that corresponds to a 24 to 48 feeding bout of an adult female grizzly bear (Mattson 1993; Mace et al. 1996). Daily winter movement rates of woodland caribou in Alberta average 0.64 km/day (Stuart-Smith et al. 1997; Smith et al. 2000), which translates to a 24 to 48 hour range area of 130 to 515 ha.

Dzus (2001) concluded that the challenge for caribou conservation is to maintain sufficient quantities of suitable habitat through time in each caribou range and not unduly increase predation pressure. He recommended that cumulative effects thresholds be developed and incorporated into range management plans. The Alberta Boreal Caribou Committee guidelines also identify the need for habitat effectiveness and activity targets (BCC 2001). Preliminary analyses suggest that a habitat effectiveness threshold occurs below which caribou populations go into decline (BCC 2001); the threshold value was not reported.

Recommended and established land use guidelines for woodland caribou are summarized in Table 22.

Table 22. Indicators and guidelines for woodland caribou.

Indicator	Guideline or Threshold	Comments
Edge Use	▪ Boreal ecotype woodland caribou under-used areas <500 m of old wells during late winter and calving <250 m of these same features during summer; they also under-used areas <250 m of roads and <100 m of cutlines during late winter (Dyer 1999).	▪ Based on studies in north central Alberta.
	▪ Northern ecotype woodland caribou under-used areas adjacent to roads and streams but not cutlines (Oberg 2001).	▪ Based on studies in Alberta foothills adjacent to British Columbia border.
	▪ Predation rates for caribou may be higher <500 m of linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000).	▪ Based on studies in north central Alberta.

Table 22. Indicators and guidelines for woodland caribou (cont'd).

Core Area	• Boreal-ecotype woodland caribou populations declined when core area <50%; threshold identified at <60% core area (Francis et al. 2002).	• Threshold based on review of Alberta population data; used 250 m buffer from all linear features.
Road Density	• Density of calving barren-ground caribou highest at road density of 0 km/km^2 and declined by 86% at road densities >0.6 km/km^2; male and yearling density highest at 0.3-0.6 km/km^2 (Nellemann and Cameron 1998). • Road densities <0.6 km/km^2 in winter range used by northern-ecotype caribou (Salmo unpub. data).	• Based on studies in Alaska petroleum development areas. • Based on studies in west central Alberta.
Corridor Density	• Boreal-ecotype woodland caribou populations declined when total corridors >1.8 km/km^2 (Francis et al. 2002). • Boreal-ecotype woodland caribou populations do not persist when total corridors >3 km/km^2 (B. Stelfox pers. comm.).	• Threshold based on review of Alberta population data. • Threshold identified by caribou biologists in Delphi process.

7. INDICATORS FOR NORTHEAST BRITISH COLUMBIA

In broad terms, resource development in northeast British Columbia is be conducted such that natural characteristics and wildlife habitat are maintained over time. In the Muskwa-Kechika Management Area, the management intent is to "…maintain in perpetuity its wilderness quality, and the diversity and abundance of wildlife and the ecosystems on which it depends…" (Muskwa-Kechika Management Act).

Reid (1993) reached the following conclusion on cumulative effects evaluation methods:

> *"When methods originate from management agencies, they tend to be simple, incomplete, theoretically unsound, unvalidated, implementable by field personnel, and heavily used. Methods developed by researchers are more likely to be complex, incomplete, theoretically sound, validated, require expert operators, and not used" (p. 35)*

In other areas, resource managers have concluded that a complementary suite of habitat and land-use indicators is the most practical and effective choice for cumulative effects assessment and management (Axys 2001b; BCC 2001). Land-use thresholds have been applied in Canadian national parks; research is underway to establish disturbance-based thresholds for grizzly bear and boreal-ecotype caribou in Alberta (Dugas and Stenhouse 2000; BCC 2001).

All indicators and thresholds presented here have some value for resource management. However, some commonly used indicators are not necessarily practical for cumulative effects assessment and management. Population-based indicators require substantial supporting data and longer lead times, and are at best indirectly linked to proposed development activity. Biodiversity and risk-based indicators are most appropriate in specific assessments where specific features or communities/species of concern are the management focus. Derivation of risk-based indicators may also require substantial supporting data and longer lead times (Dugas and Stenhouse 2000; Axys 2001b; BCC 2001; Salmo et al. 2001).

Indicators adopted for northeast British Columbia will be most effective when they are:

- based on management objectives identified in the Dawson Creek, Fort St. John, and Fort Nelson Land and Resource Management Plans (LRMPs),
- readily calculated, understood, and monitored,
- theoretically sound and science-based, ideally using regional data,
- protective of fish and wildlife species of management and public concern,
- compatible with existing development review and assessment processes, and
- applicable to a wide range of ecological settings and development activities.

7.1 RECOMMENDED CUMULATIVE EFFECTS INDICATORS

Based on the literature review, the complementary suite of cumulative effects indicators presented in Table 23 is most appropriate for cumulative effects assessment and management in northeast British Columbia. These generalized indicators are applicable to a wide variety of terrestrial and aquatic species, and do not require detailed site- or species-specific information to be applied.

Table 23. Generalized cumulative effects indicators for northeast British Columbia.

Habitat Indicators	Land Use Indicators
Core Area	**Access Density** (km of corridors per unit area)
Patch and Corridor Size	**Stream Crossing Index** (number of crossings per km of stream)
No Net Habitat Loss	**Activity Setbacks**

Access density is the best known and most widely applied land-use and access density indicator. This index represents the total length of roads or other linear corridors present in a defined land area or watershed. It is usually expressed as km/km^2. It is a useful summary index because it integrates so many ecological effects of roads and vehicles (Forman and Hersperger 1996).

Stream crossing index is an easily calculated measure of sediment and mortality sources and stream habitat fragmentation in a watershed. It is expressed as the number of road, utility corridor, or cutline crossings per kilometre of stream. A watercourse that is repeatedly crossed is more likely to suffer increased erosion and water temperature, have higher fishing pressure, and have temporary or permanent barriers to fish passage.

Remaining **core area** is a widely used habitat index that identifies the availability and location of areas with minimal human impacts. Core areas are relatively undisturbed, 'wilderness' areas that are often source areas for plant and animal populations or metapopulations.

Patches and **corridors** are reasonably uniform areas and linear features that differ from their surroundings. Patch and corridor criteria can help define suitable habitat in fragmented landscapes. In the habitat fragmentation process, there appear to be 'critical thresholds' where rapid changes in patch size and isolation occur; criteria should reflect these critical thresholds.

No net habitat loss is an indicator that is routinely applied to protect fisheries habitat. Although unavoidable habitat loss may be legally authorized at the regulator's discretion, it requires implementation of Enhanced Protection Measures, namely negotiation of a formal agreement to compensate for lost habitat. This requires habitat loss to be quantified and offset (DFO 1999).

While **activity setbacks (buffers)** are not indicators or thresholds in the sense described in this report, they are effective in protecting sensitive ecological sites (e.g., spawning and nesting areas), and thereby minimizing both project-specific and cumulative effects. Ideally, buffers used to calculate habitat and land use indicators should be based on established setbacks to help integrate assessment and management at all scales.

These indicators are tested in the Case Studies using detailed regional data (Appendices 2 and 3).

7.2 CUMULATIVE EFFECTS THRESHOLDS

Indicators present information about the likelihood of adverse cumulative effects, but do not directly measure the acceptability of these effects. Thresholds are objective, science-based standards used to define the point at which the indicator changes from an acceptable to unacceptable condition.

Established chemical thresholds are available to help proponents and regulators identify the point or range at which cumulative effects on air and water quality changes from an acceptable to an unacceptable condition. This allows development activities to proceed without detailed review until a defined threshold is reached. Once the threshold range is reached, however, additional review or regulation is implemented.

The British Columbia Approved Water Quality Guidelines (MELP 2001) are an example of science-based thresholds. Water quality problems are considered non-existent if the substance concentration is below the guideline value. In cases where the substance concentration exceeds its guideline, an enhanced evaluation of water quality is desirable. In some instances, local "Water Quality Objectives" may be developed to protect the most sensitive water use at a specific location, accounting for local circumstances (MELP 2001).

There is inevitably some uncertainty with science-based thresholds, and economic, social, and technical factors are normally considered when thresholds are established. Regulators may build in a safety margin by establishing a threshold below the point of irreversible effects or below the lowest point at which a behavioural, physiological, or population-level effect has been detected. In other cases, regulators may adopt a less stringent threshold that provides a lower, but still adequate level of protection at less cost to the proponent or society. Regardless, the rationale for threshold derivation should be clear and the process used to derive the threshold should be transparent.

Ecological thresholds have not been as widely applied as chemical thresholds, but thresholds based on meaningful ecological indicators can also be used to evaluate the acceptability of project-specific and cumulative effects.

7.2.1 Tiered Thresholds

The tiered threshold approach has been recommended since it provides a clear and integrated framework for derivation and implementation of ecological thresholds. With this approach, science-based and politically defined targets can be integrated with defined management actions so that operating rules are clear for all parties. As well, tiered thresholds provide the flexibility necessary for different land management regimes and ecological settings, and for a full spectrum of development proposals.

The primary strength of tiered thresholds is the formal link between predefined thresholds and management actions. Cautionary, Target, and Critical thresholds are defined to reflect increasing degrees of concern. A secondary asset is that tiered thresholds implicitly recognize the uncertainty inherent in our understanding of complex ecological relationships. In doing so, they provide a framework to gather data on actual responses and modify management actions where appropriate.

In northeast British Columbia, tiered thresholds can be directly related to objectives established in approved LRMPs, Landscape Unit Plans, or defined management areas. Risk-based thresholds would be most conservative in Protected Area and Special Management Zones (RMZs), intermediate in General Management RMZs, and most liberal in Enhanced Resource Development and Agriculture/Settlement RMZs.

To be most effective, cumulative effects thresholds must be able to deal with the full spectrum of development proposals, ecological settings, and administrative boundaries. In northeast British Columbia, project proposals are likely to undergo one of three types of regulatory review:

1. **Routine Review**: Simple or normal proposals with limited potential for significant adverse cumulative effects.
2. **Enhanced Review**: Simple or normal proposals in sensitive areas or those with some potential for significant adverse cumulative effects.
3. **Complex Review**: Complex proposals with high potential for significant cumulative effects

Table 24 summarizes the desirable indicator attributes for each review class, and provides examples of generalized, terrestrial, and aquatic indicators and thresholds.

Section 4 of the main report (Conclusions) presents candidate thresholds for the core area, patch and corridor size, access density, and stream crossing indicators.

Table 24. Desirable threshold attributes for cumulative effects assessment in northeast British Columbia.

	Routine Review *(Most Practical)*	Enhanced Review *(Intermediate)*	Detailed Review *(Most Comprehensive)*
Attributes	▪ Quickly and cheaply calculated ▪ Least data required ▪ Limited need for specialized expertise ▪ Standardized and generally applicable ▪ Easily measured and enforced ▪ Indirect measure of effects	▪ Quickly and cheaply calculated ▪ Moderate data requirements ▪ Specialized expertise generally needed ▪ Regional or RMZ-specific ▪ Measurable and enforceable	▪ Expensive and protracted to develop ▪ Comprehensive, site-specific data required ▪ Specialized expertise required ▪ Site-specific ▪ Most difficult to measure and enforce ▪ Direct measure of effects
Generalized Examples	▪ Maximum Access Density ▪ Maximum Disturbance ▪ Maximum Activity Level	▪ Maximum Access Density by Use Intensity	▪ Access Management Plan ▪ No Net Change in Carrying Capacity
Terrestrial Examples	▪ Maximum Road Density ▪ Minimum Corridor Width ▪ Minimum Patch Size	▪ Maximum Species-specific Road Density ▪ Minimum Habitat Effectiveness ▪ Maximum mortality rate	▪ Linkage Zone Modelling ▪ Minimum Viable Population Size ▪ Minimum Cow/Calf Ratio
Aquatic Examples	▪ Minimum Roadless Area ▪ Road Density Hazard Level ▪ Stream Crossing Density ▪ Riparian Road Density ▪ Riparian Clearing ▪ Maximum Surface Water Drawdown	▪ No Net Loss of Fish Habitat ▪ Road Density on Unstable Slopes or Erodible Soils ▪ Riparian Clearing on Unstable Slopes or Fish-bearing Streams	▪ Linkage Zone Modelling ▪ No Net Loss of Productive Capacity ▪ Minimum Viable Population Size

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Cumulative Effects Assessment and Management Framework
for
Northeast British Columbia

Volume 2
Cumulative Effects Indicators, Thresholds, and Case Studies

Appendix 2
Blueberry Cumulative Effects Case Study

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GLOSSARY

Access corridor – a linear feature created by humans (road, trail, pipeline, powerline, railway line, cutline) that may be used by pedestrians, vehicles, hunters, anglers, or animal predators.

ALCES – 'A Landscape Cumulative Effects Simulator' computer model used to forecast changes in landscape patterns and wildlife habitat. This simulator integrates four submodels (habitat availability, population, land use, and natural disturbance) and considers all land use activities likely to occur in the region. It includes both aquatic and terrestrial indicators and is able to incorporate random events such as fire.

Barrier – a barrier is present when it is not possible for animals to move across a corridor, and the habitat on either side of the corridor becomes isolated (e.g., a busy highway is a barrier for small ground-dwelling insects)

Biodiversity – the diversity of plants, animals, and other living organisms in all their forms and levels of organization (BCF and BCE 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Biogeoclimatic zone – a geographic area having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macro-climate (BCF and BCE 1995a).

Cautionary threshold – a threshold established to indicate that additional or more intensive monitoring is required to provide sufficient local data to confirm scientific predictions of both target and critical thresholds.

CEAM – Cumulative Effects Assessment and Management framework consisting of an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley; windrow, aeolian ridge) or as the result of human disturbance (e.g., roads, cutlines).

Critical threshold – a science-based target reflecting the continuous maximum amount of stress that a sensitive ecosystem or species can support without sustaining long-term harm. This may incorporate economic and social values to determine the acceptable magnitude of change, risk of long-term damage, or level of protection required.

Cumulative effects – changes to the environment caused by collective past, present, and future human actions; most result from the combined effects of simple, routine activities and projects.

DC – Disturbance Coefficient; an index assigned to each feature or activity type that rates the degree to which the disturbance zone of influence remains effectively useable by the species. Ratings are on a scale of 0 to 1 and are used to calculate habitat effectiveness.

Density-dependent – factors that affect population growth and parameters in relation to as animal abundance. These depress population growth as animal abundance increases, and increase growth as animal abundance decreases. Examples include food availability and quality. Predation may be density-dependent or –independent.

Density-independent – factors that affect population growth and parameters regardless of animal abundance. Examples include natural environmental disturbances such as fire, floods, or severe weather. Predation may be density-dependent or –independent.

Disturbance – a natural or human action that affects physical, chemical, or biological conditions.

Disturbance feature – a corridor or patch created by natural random events (e.g., burn or flood) or human action (e.g., cutblock, facility, community, road).

Disturbance trajectory – the calculated or predicted rate of natural or human disturbance.

Drainage - a subset of a watershed, generally less than 1,000 km^2 in size.

Early seral – forest that are younger than 40 years old (BCF and MELP 1999b).

Ecological resilience – the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996).

Ecological sink – an area with degraded habitat that has lower survival (or higher mortality) rates, causing local population declines. Although individual animals may continue to use this area, it creates a net loss to the population that may not be detectable for several generations.

Edge area - the area bordering patches and corridors where abiotic conditions (e.g., moisture, light, temperature, wind regimes) and biotic conditions (e.g., predation, mortality, competition, vegetation diversity and structure, species diversity and abundance) may be altered. Examples include the intersection between a cutblock and forest or a trail and native grassland.

Filter or porous barrier – a type of corridor across which some movement occurs but the rate of movement is less than through intact habitat (e.g., a busy highway is a porous barrier for large mobile wildlife like deer [*Odocoileus* spp.]).

Fragmentation – the process of losing habitat continuity through temporary or permanent conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). Three general effects result from habitat fragmentation: (1) original habitat is lost, (2) remaining habitat patches decrease in size, and, (3) patches become increasingly isolated from one another.

Habitat – the environment in which an organism or biological population lives or grows.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest regrowth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production; introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat availability – the amount of usable habitat accessible to a particular species.

Habitat capability – the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999).

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness for that species.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and regrowth is not allowed to occur (e.g., construction of a city, highway or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Habitat suitability – the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (RIC 1999).

Habitat unit – a defined terrestrial or aquatic unit with consistent abiotic and biotic conditions.

Hazard level – the risk of an adverse cumulative hydrological effect defined by the British Columbia Interior Watershed Assessment Procedure (IWAP; BCF and BCE 1995b; BCF 1999).

Human activity – all forms of human actions including land conversion and disturbance, damming, water withdrawal, pedestrian, vehicle and aircraft movements, harassment, harvest, and contaminant input.

Index or metric – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator – a surrogate measure used to represent or monitor the condition of an abiotic or biotic resource. May be a representative species, an outcome, or an input.

Interior area – also referred to as core area in this report. Interior areas are those beyond the influence of edge effects.

IWAP – Interior Watershed Assessment Procedure; a method developed by the provincial government to help forest managers understand the type and extent of current water-related problems in a watershed, and to recognize the implications of proposed activity in that watershed (BCF 1999).

Juvenile – an individual age 1 or older that has not reached maturity.

Landscape – an area of tens to hundreds of square kilometres that includes one dominant background ecosystem. Northeast British Columbia consists of a number of landscape types including the forest landscape, the agricultural landscape, and the alpine/subalpine landscape.

Local population - A breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Lowest observed effect level – concept from the field of ecotoxicology that represents the lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms compared to the controls. Also called lowest observed adverse effect level (LOAEL). This concept is also applicable to behavioural, physiological, and population response.

LU – Landscape Unit; an area of land and water used for long-term planning of resource management activities according to the *Forest Practices Code of British Columbia Act*. It may be used for designed strategies and patterns for landscape level biodiversity and for managing other forest resources (BCF and MELP 1999b).

LRMP – Land Resource Management Plan; a plan approved by the provincial government that establishes direction for land use and specifies broad resource management objectives and strategies.

Matrix – the dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Mature growth/mature seral – forests greater than a specified age (generally >80 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Metapopulation - a population of populations. This represents an abstraction of the population concept to a higher level. Metapopulations generally consist of a group of interacting but spatially discrete or isolated populations, subpopulations, or stocks. These subunits are linked by drainage networks but movement between subunits is infrequent and typically takes place across unsuitable habitat or over great distances (Hanski and Gilpin 1991; Dunham and Rieman 1999). An example of a fish metapopulation is a group of isolated headwaters populations found in the same watershed.

MSRM - British Columbia Ministry of Sustainable Resource Management

Natural disturbance type – an area characterized by a natural disturbance regime. The provincial government has established five natural disturbance types for managing biological diversity according to the *Forest Practices Code of British Columbia Act* (BCF and BCE 1995a; BCF and MELP 1999b).

OGC – British Columbia Oil and Gas Commission.

Old growth/old seral – forests greater than a specified age (generally >100 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches can occur naturally (e.g., sloughs, burns) or as the result of human disturbance (e.g., farmyards, wellsites, clearcuts).

Population – a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population limiting factors – processes that quantifiably affect the population rate-of-increase. Responsible for inducing year-to-year changes in animal abundance (Messier 1991).

Population regulating factors – density-dependent processes that ultimately keep populations within normal density ranges. These are a subset of limiting factors and predictably depress population growth as animal abundance increases (Messier 1991).

Reach – a defined watercourse channel section, tens to thousands of meters in length, with relatively consistent channel morphology, hydrology, and water chemistry.

Regional - an area more than hundreds of square kilometres that incorporates several landscapes.

Riparian - the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995c; BCF and MELP 1999b).

Riparian clearings - cleared areas within 15 m of a waterbody, including linear corridors, communities and residences, industrial and commercial facilities, cutblocks, and agricultural fields.

Riparian roads - roads and trails within 100 m of a waterbody.

RMZ – Resource Management Zone; defined subdivisions of an approved LRMP that have unique sets of resource values, objectives to maintain or enhance those values, and a number of strategies to be implemented to achieve those objectives. These provide geographically-focused, strategic direction (Fort St. John LRMP 1997).

Seral stage – the stages of natural ecological succession of a plant community, for example from young through mature to old stage (BCF and BCE 1995a).

Stream crossing - a road, trail, pipeline, powerline, railway line, or cutline crossing of a watercourse.

Subpopulation - a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Subwatershed - a subset of a watershed, generally less than 1,000 km^2 in size.

Target threshold – a politically-defined goal reflecting the optimum amount of stress on the system. This threshold is more protective than the critical threshold to provide a margin of safety. A target threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

Threshold – a point at which a resource changes to an unacceptable condition, with acceptability defined either from an ecological or social perspective.

Viable population – a self-sustaining population with a high probability of survival despite the foreseeable effects of demographic, environmental, and genetic stochasticity and of natural catastrophes (BCF and BCE 1995a).

Waterbody – a specific aquatic basins or channel (lake, pond, wetland, river, or stream).

Watercourse – a specific flowing channel (river or stream).

Watershed – a large drainage area, generally 1,000 to 10,000 km^2 in size, which flows directly into a large river such as the Peace River.

WHA – Wildlife Habitat Area contain critical habitat elements for one or more species of Identified Wildlife. These areas are mapped and approved by the Chief Forester and WLAP according to the *Forest Practices Code of British Columbia Act*.

WLAP – British Columbia Ministry of Water, Land and Air Protection.

ZOI – Zone of Influence; the distance to which a species is affected by an activity or disturbance.

1. INTRODUCTION

As part of the British Columbia Oil and Gas Commission's (OGC) initiative to address environmental effects associated with oil and gas development, an environmental fund was established for research projects over a five-year period. Cumulative effects was one of three research envelopes for which funding was provided.

Salmo Consulting Inc. (Salmo), Diversified Environmental Services (Diversified), Axys Environmental Consulting Ltd. (Axys), and GAIA Consultants Inc. (GAIA) received funding under the Cumulative Effects Research envelope to conduct three separate but integrated studies. In combination, these studies will provide an over-arching strategy and approach for identifying, scoping, assessing and managing cumulative effects in northeast British Columbia (hereafter referred to as cumulative effects assessment and management, or CEAM). The three components are:

- Development of an overall **CEAM Framework**.
- Detailed assessment of cumulative effects in two **Case Studies**.
- Development of a **Decision Support** system.

All components contribute to the development of a framework to aid the OGC in ensuring that cumulative effects are consistently addressed and managed as part of their ongoing project approval process.

The Cumulative Effects Indicators, Thresholds, and Case Studies (Case Studies) component, conducted by Salmo, Diversified, Gaia, and Forem Technologies Ltd. (Forem), is intended to help test and develop approaches for assessing cumulative effects, determining impact significance using actual data from two representative areas in northeastern British Columbia (Blueberry and Sukunka).

This report provides the case study for the Blueberry representative area. It is divided into three main sections:

Section 2. Regional Setting

- Summarizes information on the biophysical and administrative setting relevant to environmental planning and management in the Blueberry Case Study area.

Section 3. Development and Resource Trends

- Describes a Geographic Information System (GIS) database created for the Blueberry Case Study area from readily-available government sources.
- Reviews land use, human activity, and renewable resource information to document historical trends and current conditions.
- Describes projections of future land use and human activity patterns and possible renewable resource availability, abundance, and distribution.

- Relates historical and future renewable resource trends to land use and human activity patterns and identifies apparent thresholds.

Section 4. Cumulative Effects Criteria and Thresholds

- Evaluates applicability of cumulative effects analyses and ecological, land use, and social thresholds in the Blueberry Case Study area.
- Evaluates utility of readily available data for cumulative effects models and assessments.

2. REGIONAL SETTING

The Blueberry Case Study was conducted in a 2,690 km^2 area northwest of Fort St. John, immediately northeast of the community of Wonowon (Figure 1). The Case Study area is bounded by the Alaska Highway to the south, Longitude 122° to the west, the Beatton River to the north, and Longitude 121° 20' to the east. Agricultural, residential, and infrastructure development has occurred over approximately 40% of the Blueberry area; the remainder is forested and managed for multiple land use (Figure 2).

Regional and local climatic patterns in this region are strongly influenced by the Rocky Mountains and both Pacific and Arctic air masses. The climate is characterized by cool, short summers and cold winters with severe temperatures moderated by frequent chinooks. When Pacific weather systems move in from the west, precipitation is deposited on the western slopes of the mountains; regions to the north and east are sheltered and drier. During the winter, the mountains block the advance of cold Arctic air masses from the north and northeast, and the northeast region is colder. The combined effect is lower annual precipitation (400 to 600 mm) and annual mean temperatures (approximately -0.5°C) east of the Rocky Mountains.

The area east of the Rocky Mountains is classified as the Alberta Plateau or Boreal Plains Ecoprovince and consists of a plateau of fine-textured soil with deeply incised streams. Topographic relief on this plain increases from east to west. The Blueberry study area lies near the western edge of this plateau within the Halfway Plateau Ecosection. This ecosection is a rolling upland with some higher ridges and wide valleys dissected by small, southward flowing streams. Numerous wetlands and slow-moving streams are present.

Gray Luvisols developed on moderately fine-textured morainal deposits are the dominant soil type. Some clayey lacustrine deposits are present in valleys and these may have over 50% organic soils. Organic soils occur in poorly drained lowland areas and Brunisols are present on steep slopes. Permafrost is limited to isolated patches along the northern boundary of the ecoregion.

The Blueberry study area is entirely within the Boreal White and Black Spruce (BWBS; *Picea glauca* and *P. mariana*) biogeoclimatic zone, an extensive belt of coniferous and mixedwood forest. White and black spruce, lodgepole pine (*Pinus contorta*), and trembling aspen (*Populus tremuloides*) forests dominate upland sites. Black spruce forests dominate poorly drained areas, and balsam poplar (*Populus balsamifera*) is common in riparian areas. Highbush cranberry (*Viburnum edule*), rose (*Rosa* spp.), forbs, and mosses are characteristically found in the understory. Forest fires occur frequently, and maintain most forests in various successional stages (DeLong et al. 1991).

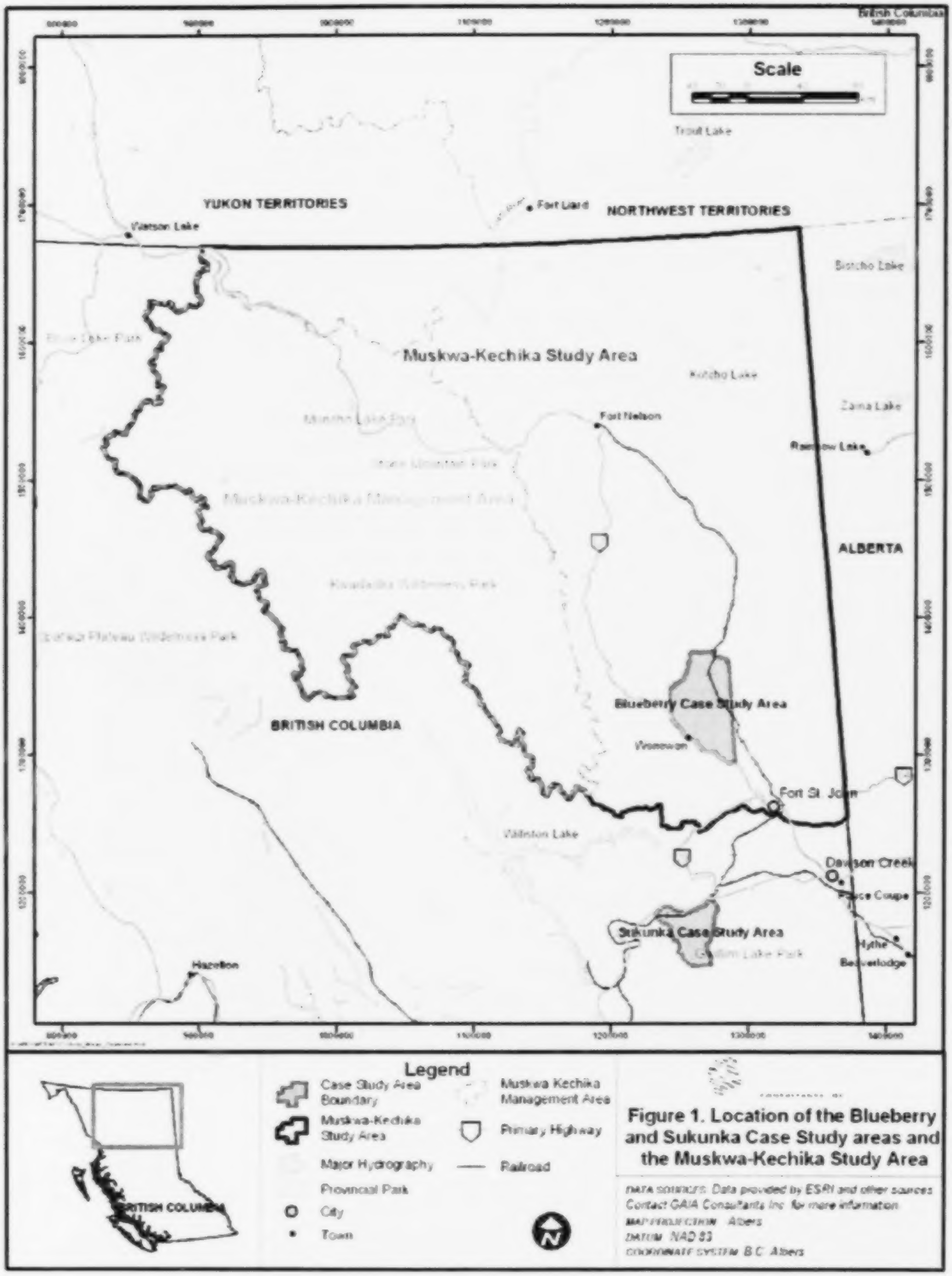


Figure 1. Location of the Blueberry and Sukunka Case Study areas and the Muskwa-Kechika Study Area

DATA SOURCES: Data provided by ESRI and other sources
Contact GAIA Consultants Inc. for more information
MAP PROJECTION: Albers
DATUM: NAD 83
COORDINATE SYSTEM: B.C. Albers

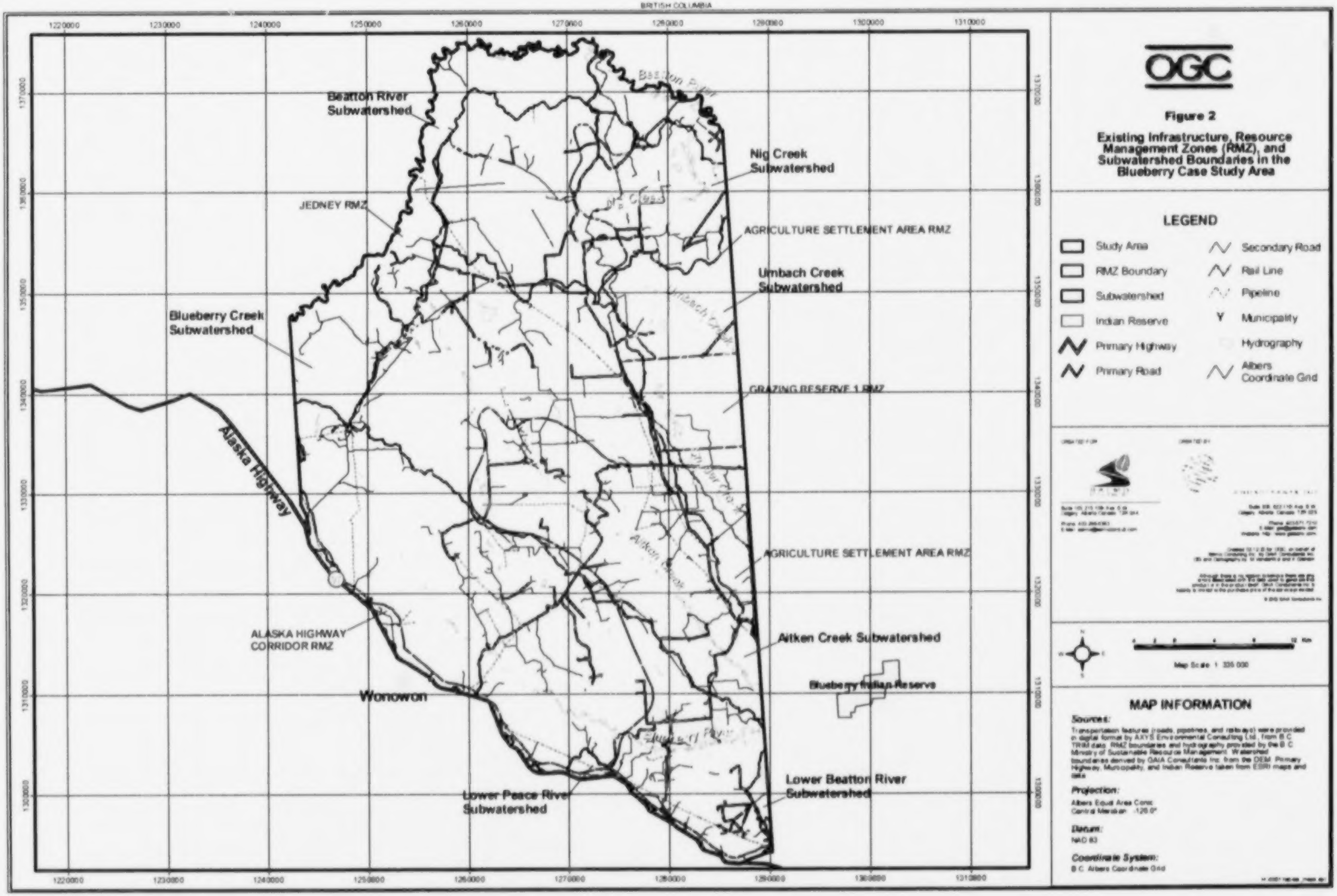


Figure 2

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Blueberry Case Study Area

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from the DEM. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

The BWBS zone has low to moderate snow accumulation and provides important ungulate wintering habitat. Wildlife in the region includes moose (*Alces alces*), deer (*Odocoileus* spp.), elk (*Cervus elaphus*), woodland caribou (*Rangifer tarandus*), black bear (*Ursus americanus*), beaver (*Castor canadensis*), mink (*Mustela vison*), wolf (*Canis lupus*), marten (*Martes americana*), hare (*Lepus americanus*), and spruce grouse (*Dendragapus canadensis*).

The Blueberry area is almost entirely within the Beatton River watershed, primarily the Blueberry River (31%) and Aitken Creek (30%) subwatersheds. Other larger subwatersheds include Nig Creek (16% of the study area), Umbach Creek (10% of the study area), and minor tributaries to the Beatton River (12% of the study area). The Lower Peace River subwatershed includes a very small area (<0.5% of the study area) along the Alaska Highway (Figure 2).

2.1 ADMINISTRATIVE

The closest communities are the hamlet of Wonowon located on the southwest boundary of the study area, and the Blueberry and Halfway Indian Reserves located about 30 km to the east and southwest, respectively. The City of Fort St. John is located approximately 60 km to the southeast via the all weather Alaska Highway.

A wide variety of human activities occur in the Blueberry study area, including oil and gas development, forest harvest, agriculture, and recreational and subsistence renewable resource use. The level of activity has increased dramatically over the last 40 years (FSJ LRMP 1997).

Overall guidance for land and resource use is provided by the Fort St. John Land and Resource Management Plan (FSJ LRMP 1997). Provisions of this plan and other applicable management guidance documents are summarized below.

2.1.1 Fort St. John Land and Resource Management Plan

The FSJ LRMP area includes approximately 46,700 km^2 of Crown land within the Fort St. John Forest District. The FSJ LRMP (1997) provides a strategic planning framework for resource development and use outside of Protected Areas, based on the principles of integrated resource management. The overall objective of the FSJ LRMP is to ensure sustainable management of land, resources, water and ecosystems within the planning area.

The FSJ LRMP identifies five Provincial Land Use Categories that reflect general management regimes:

- The *Agriculture/Settlement* category, comprising 12% of the planning area, include lands currently used or with development potential for settlement, agriculture and range, or in the Agricultural Land Reserve (ALR).

- The *Enhanced Resource Development* category, comprising 20% of the planning area, includes lands with existing or future potential suitability for intensive resource development where resource development and enhancement are encouraged in compliance with the existing regulatory regime.
- The *General Resource Development* category, comprising 46% of the planning area, includes lands to be managed for a wide range of resource values and where resource development is integrated with environmental and conservation values. The *Special Resource Management* category, comprising 18% of the planning area, includes areas where specific resource uses are to be given a high priority in planning and development. These include: Tourism and Visual Quality; Fish and Wildlife Habitat; Wilderness and Backcountry Recreation; Major River Corridors; and Community Water Supply.
- The *Protected Area* category, comprising 4% of the planning area, includes all Goal 1 and 2 areas proposed under the Protected Areas Strategy (PAS).

The management unit specified by the FSJ LRMP is the Resource Management Zone (RMZ). The planning area is divided into 27 RMZ's based on resource and environmental values, economic activity, and ALR boundaries. Specific land management objectives and strategies are provided for each RMZ.

Over 98% of the Blueberry study area is included in the Agriculture/Settlement and Enhanced Resource Development land use categories where resource development is identified as the priority land use. As shown in Figure 2, four RMZ's are present within the case study area:

1. Jedney Enhanced Resource Development RMZ.
2. Agriculture/Settlement Area RMZ.
3. Grazing Reserve 1 Enhanced Resource Development RMZ.
4. Alaska Highway Corridor Special Management – Tourism/Visual Quality RMZ.

2.1.1.1 Jedney Enhanced Resource Development RMZ

Approximately 60% of the Blueberry study area is within the Jedney Enhanced Resource Development RMZ. This RMZ contains proven and potential natural gas reserves, high coniferous and deciduous timber values, as well as existing and potential agricultural operations and grazing areas. The northern portion of the RMZ provides high capability habitat for moose, caribou, grizzly bear (*Ursus arctos*), black bear, furbearers, and birds. Most sport fish species are present in the RMZ, but Arctic grayling (*Thymallus arcticus*) are the most widely distributed and abundant.

Planning objectives for the Jedney RMZ allow for a full range of resource uses, provided an appropriate regulatory framework is applied. Specific objectives include:

- Maintain opportunities and access for minerals and oil and gas exploration and development;

- Enhance timber harvest and maintaining a sustainable timber supply;
- Provide a full range of recreation opportunities;
- Provide opportunities for growth of agriculture and livestock grazing;
- Coordinate access and linear development to minimize negative effects on other resource values;
- Maintain high capability ungulate winter habitat and habitat for priority fish and wildlife species; and
- Sustain natural stream flow regimes.

2.1.1.2 Agriculture/Settlement Area RMZ

The Agriculture/Settlement Area RMZ comprises 35% of the Blueberry study area. Agriculture is the dominant land use in this RMZ, and most land is privately owned. Oil and gas tenures and infrastructure are also present and there is potential for industrial mineral and aggregate extraction. There is good potential for deciduous timber harvest, mainly on private land. Critical ungulate winter range is provided by south-facing slopes of most streams and rivers, and the area is an important flyway and staging area for migrating waterfowl (FSJ LRMP 1997).

Planning objectives for the Agriculture/Settlement Area RMZ include:

- Maintain opportunities and access for minerals and oil and gas exploration and development while minimizing impact to local residents;
- Maintain timber harvest and forest management opportunities and minimize losses to the timber land base;
- Provide a full range of recreation opportunities;
- Maintain or increase land supply for agriculture and grazing including access to Crown Land;
- Minimize or mitigate wildlife impact on agricultural enterprises;
- Maintain existing access and coordinate industrial access development to minimize negative effects on other resource values;
- Protect or enhance habitats for red and blue listed species, maintain high capability ungulate wintering habitat, and maintain site-specific habitats;
- Maintain fish habitat and water quality for priority fish species; and
- Sustain natural stream flow regimes.

2.1.1.3 Grazing Reserve Enhanced Resource Development RMZ

Grazing Reserve 1, one of five reserves in the region, is located at the eastern edge of the Blueberry study area. This reserve covers about 3% of the study area. Agriculture and range are the primary existing activities in the Grazing Reserves RMZ; petroleum development is also present. The Grazing Reserves contain high capability winter habitat for moose and deer, and important wetland habitats for waterfowl. Habitat for priority fish species exists adjacent to the Grazing Reserves (FSJ LRMP 1997). Hunting is the primary recreational activity.

Planning objectives for the Grazing Reserves RMZ include:

- Maintain opportunities and access for minerals and oil and gas exploration, development, and transportation;
- Maintain timber harvest and forest management opportunities and minimize losses to the timber harvesting land base;
- Integrate recreational opportunities with other land uses (i.e., grazing and resource extraction);
- Maintaining or enhancing opportunities for livestock grazing and minimizing/mitigating wildlife impact on agricultural enterprises; and
- Maintaining high capability habitat for ungulate and priority fish species and manage wetland habitat for waterfowl.

2.1.1.4 Alaska Highway Corridor Special Management RMZ

The Alaska Highway Corridor RMZ includes the area visible from the Alaska Highway, and the width of the corridor, therefore, is dependent on topography. Visitors traveling the highway participate in hiking, fishing, camping, wildlife viewing and sightseeing activities. Resource extraction industries are managed to maintain the visual qualities. Vehicle/animal (cattle and wildlife) collisions are an ongoing safety concern (FSJ LRMP 1997).

Planning objectives for the Alaska Highway Corridor RMZ focus on maintaining the visual, recreational, and historical values of the landscape while allowing for economic opportunities. Specific objectives include:

- Maintaining opportunities and access for mineral/aggregate extraction and oil and gas exploration and development;
- Maintaining timber harvest and forest management opportunities;
- Providing a full range of quality public and commercial recreation opportunities and values;
- Maintaining or enhancing opportunities for livestock grazing while managing safety concerns associated with livestock within the highway corridor;
- Maintaining site-specific wildlife habitats and developing plans to prevent or minimize vehicle/wildlife conflicts; and
- Maintaining habitat for fish at highway stream crossings.

2.1.2 Wildlife Management Plans

2.1.2.1 Provincial Strategies

The Provincial Wildlife Strategy (MELP 1994) provides a framework for wildlife program planning and prioritization. Wildlife management will be based on the principles of ecosystems and population management using best available biological, ecological, and social information. Specified goals include:

- Maintain diversity and abundance of native species and their habitats throughout British Columbia.
- Provide a variety of opportunities for the use and enjoyment of wildlife.
- Balance needs of wildlife and needs of people.

The Wildlife Harvest Strategy (MELP 1996) provides the framework for management of game species. Species-specific management standards are provided for caribou, deer, elk, moose, black bear, grizzly bear, cougar (*Felis concolor*), wolf, migratory game birds, upland game birds, and furbearers.

2.1.2.2 Regional Wildlife Plan for the Peace Sub-region

The Blueberry Case Study area covers approximately one-third of provincial wildlife Management Unit 7-45 (MU 7-45). Harper (1988) prepared a regional wildlife management plan for the Peace sub-region that includes specific recommendations for MU 7-45. The following habitat management strategies apply to the Blueberry Case Study area:

- Prepare a prescribed fire plan based on biophysical ungulate capability mapping to enhance Class 3W and better moose habitats to carrying capacities able to support 2,000 additional moose in Management Unit 7-45;
- "Red-flag" trumpeter swan (*Cygnus buccinator*) habitats as they become known and prohibit industrial activity within 0.5 km during the summer months; and
- Identify critical furbearer habitats and protect from silvicultural use of herbicides, and formulate guidelines that incorporate furbearer habitat requirements into prescriptions for herbicide use on non-critical furbearer habitats.

Harper (1988) also identified the following species-specific status and recommended management objectives and activities:

Moose – Mid-1980's population in MU 7-45 is approximately 2,200, well below estimated habitat capability. Increase population in MU 7-45 by 25% to about 4,400 moose by the year 2000 and provide a hunter success rate of 40% with a moose killed for every 15 days hunted. To be achieved through habitat protection and enhancement, reducing non-hunting mortalities, and introducing an intensive inventory program to monitor population trends and regulate harvest.

Grizzly Bear – Mid-1980's population in MU 7-45 is approximately 60 with an annual allowable harvest of 2 bears. Maintain the grizzly bear population in MU 7-45 at current levels. To be achieved by regulating sport harvest to 2% females and 6% males, monitoring kill locations to avoid local overharvesting, and minimizing bear-human conflicts.

Caribou – Caribou present only occasionally in MU 7-45 in the mid-1980's and no sport harvest allowed. Increase regional population to 2,500 (over 125%) by the year 2000 if predation is not limiting. To be achieved through regulated male-only harvest, regulating harvest of mature lodgepole pine stands, and intensive inventory to document population dynamics.

Elk – Elk assumed to be absent from MU 7-45 in the mid-1980's. Double the regional population to 2,400 by the year 2000. To be achieved through habitat protection and enhancement, elk transplants, regulating harvest, and introducing an intensive inventory program to monitor population dynamics and trends.

Deer – 1987 mule deer (*Odocoileus hemionus*) population approximately 400 in MU 7-45, slightly above estimated habitat capability. Deer populations to be maintained at, or slightly above current level. To be achieved through supplementary feeding during severe winters, harvest regulation, and protection of important winter ranges.

Black bear – Mid-1980's population in MU 7-45 is approximately 1,000 to 1,700. Reduce current regional populations by about 20% by controlling nuisance bears, minimizing bear-human conflicts, and adjusting harvest to manage the population size and distribution.

Wolf – Mid-1980's population estimated to be 40 to 60. Maintain wolf numbers within the agricultural area at current levels and allow numbers to fluctuate naturally in the rest of the sub-region. To be achieved by allowing generous harvest, and predator control assistance. In the Blueberry study area, wolf control to be provided only on private lands where livestock depredation occurs.

Furbearers – Mid-1980's population status for 15 furbearer species unknown. Lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), fisher (*Martes pennanti*), and otter (*Lontra canadensis*) considered to be vulnerable to overharvest. Manage harvest with minimum regulatory control, high measure of responsibility on the Registered Trapline holder, and habitat protection through referral system.

Non-game wildlife – Management efforts to concentrate on species of concern (endangered, restricted distribution, management concern). Systematically monitor a variety of non-game species and specialized habitats (e.g., riparian balsam poplar communities, wetlands, large snags for cavity nesters) and protect key habitats through referral system.

2.1.2.3 Identified Wildlife Management Strategy

Bull trout (*Salvelinus confluentus*), fisher, grizzly bear, and trumpeter swan are classified as 'Identified Wildlife' under the Forest Practices Code (see Section 2.1.3.1). The goals of the Identified Wildlife Management Strategy are to minimize the effects of forest activities on Identified Wildlife, to maintain their limiting habitats throughout their current ranges and, where appropriate, their historic ranges. In some cases, this will entail restoration of previously occupied habitats, particularly for those species most at risk.

Identified Wildlife are managed through the establishment of wildlife habitat areas (WHAs) and implementation of general wildlife measures (GWMs) as specified in Managing Identified Wildlife: Procedures and Measures Volume 1 (MOF 1999). The purpose of WHAs is to conserve those habitats considered most limiting to a given species. GWMs describe the management practices that must be implemented within an approved WHA such as seasonal or year-round activity restrictions.

Identified Wildlife provisions are typically site-specific measures that cannot address the issues of habitat supply, habitat connectivity and population viability. Such considerations are considered in landscape level or regional plans such as the FSJ LRMP or MKMA Management Plan. Species-specific or higher level plans may be developed where provincial authorities determine that additional measures are required to conserve viable populations of a species throughout its range in British Columbia.

2.1.2.4 Provincial Species Management Strategies

Species management strategies and plans developed by the provincial government provide guidance for the following species of concern:

- British Columbia Grizzly Bear Conservation Strategy (MELP 1995).
- A Lynx Management Strategy for British Columbia (Hatler 1988).
- A Wolverine Management Strategy for British Columbia (Hatler 1989).

2.1.3 Other Management Initiatives

Other initiatives that affect resource management in the Ft. St. John planning area include the Forest Practices Code, the Oil and Gas Handbook, and First Nations interests, among others (ARA Consulting et al. 1996). Theses are discussed briefly below.

2.1.3.1 Forest Practices Code

A series of regulations, standards, and guidebooks have been developed since 1994 pursuant to the *Forest Practices Code of British Columbia Act* (the Forest Practices Code). One of the key objectives of the Code is to ensure that long-term environmental considerations are taken into full account.

Standards set out detailed requirements for activities in forested areas, including soil conservation, road and bridge construction, timber harvesting, and access management. A series of guidebooks have been prepared to help land users develop site-specific plans.

2.1.3.2 Oil and Gas Handbook

The Oil and Gas Commission has developed a series of Guidelines, Policies, Information Letters, and Information Bulletins that provide guidance on oil and gas exploration, development, and production activities in the Blueberry area. The Oil and Gas Handbook summarizes legislative requirements, regulations, procedures, and guidelines for proposed oil and gas activities and provides a starting point from which proponents can plan and undertake activities, acquire additional reference material or contact government personnel and industry associations for further assistance.

The 'Maximum Disturbance Review Criteria Operating Code and Guideline' (OGC 2002) defines acceptable siting/routing, size, spacing, and construction techniques for oil and gas development activities. Guidelines for minimum construction setbacks from sensitive habitat features are provided.

2.1.3.3 First Nations Interests

The Blueberry Case Study area is within the traditional territories of the Blueberry and Halfway First Nations. Relationships with First Nations in this region are affected by the circumstances surrounding land claims in general, Treaty 8 in particular, recent court decisions regarding aboriginal rights, and Memoranda of Understanding negotiated between First Nations and the Province.

First Nations did not participate in the FSJ LRMP process, and direct consultation with potentially affected groups is generally required before commencing industrial activities on forested Crown lands in the Blueberry area.

3. DEVELOPMENT AND RESOURCE TRENDS

This discussion of development and renewable resource trends in the Blueberry Case Study area is divided into three subsections:

Section 3.1 Mapping and Analysis Methods

- Summarizes methods used to develop the GIS database and wildlife habitat models, and complete cumulative effects analyses.

Section 3.2 Development Trends

- Describes changes land use and human activity and anthropogenic disturbance trajectories in the Blueberry area since 1950.
- Describes projections of future land use and human activity patterns for the Blueberry area.

Section 3.3 Renewable Resource Trends

- Describes changes in fish and wildlife populations and habitat in the Blueberry area since 1950.
- Describes projections of future renewable resource availability, abundance, and distribution.
- Relates historical and future renewable resource trends to land use and human activity patterns and identifies apparent thresholds.

3.1 MAPPING AND ANALYSIS METHODS

3.1.1 Geographic Information System

A Geographic Information System (GIS) database was developed for the Blueberry Case Study area by GAIA in ARCView© and ARCInfo©. This database used readily available 1:20,000 digital TRIM files provided by regional government staff, including: elevation, hydrography, forest cover, base features (roads, cutlines, pipelines, railway lines, facilities, clearings, communities), and LRMP management boundaries. Watershed and subwatershed boundaries were derived in the GIS using the digital elevation model.

3.1.2 Development and Renewable Resource Trends

Land use patterns in the Blueberry area were identified at three points in time: 1950, 1970, and current (late 1990's). Base features in 1950 and 1970 were digitized from air photographs. Current (late 1990's) conditions were obtained from TRIM files.

Harper (1988) provides the most comprehensive record of wildlife status in the Blueberry area. Hunter and trapper harvest and effort data for MU 7-45 was obtained from WLAP regional staff to document recent trends in wildlife and furbearer harvest and inferred abundance.

WLAP files were also searched to obtain any relevant information on historical fish and wildlife distribution and abundance and human activity patterns.

3.1.3 Wildlife Habitat Models

Habitat models describe or predict the physical and biological factors that are assumed to control the distribution and abundance of wildlife and fish populations. The primary purpose of habitat models is to provide a relative rating of the importance of specific vegetation or biogeoclimatic units for a particular wildlife species (Salmo et al. 2001).

3.1.3.1 Species Selection

Every species has some value for assessing environmental conditions and potential effects. However, evaluating every species in a cumulative effects assessment is impractical. An accepted approach is to select a complementary suite of representative species, groups, or guilds that are useful in quantifying or evaluating the effect of disturbance (Beanlands and Duinker 1983; Noss 1990; Cocklin et al. 1992; Smit and Spaling 1995; Noss et al. 1996). Appropriate species or guilds used for cumulative effects assessment and management are generally selected by considering the following criteria (adapted from Noss 1990):

- economic importance (e.g., **featured** species important for hunting, fishing, traditional land use, or recreation),
- sensitivity to potential development activities or early indicator of environmental stress or incremental demand on facilities and services (e.g., **ecological** and **sensitive** indicators: species that signal the effects of perturbations on a number of species with similar habitat requirements),
- importance in the food chain or ecosystem function (e.g., **keystones**: pivotal species upon which the diversity of a large part of a community depends),
- social importance (e.g., **flagships**: popular, charismatic species that serve as symbols and rallying points for conservation initiatives),
- special conservation status (e.g., **vulnerables**: species that are rare, genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise vulnerable to extinction in human-dominated landscapes),
- ecological or economic significance for more than one discipline and disturbance type (e.g., **umbrellas**: species with large area requirements that incorporate many other species),
- ability to be quickly and cost-effectively calculated, estimated or assessed from existing data sources, and

- ability to be efficiently and cost-effectively monitored.

The four wildlife species selected as indicators for the Blueberry and Sukunka Case Studies: moose, woodland caribou, elk, and grizzly bear, are high profile or sensitive species for which reasonable data are available. Representative fish (Arctic grayling and bull trout), furbearer (marten), and forest bird species (black-throated green warbler, *Dendroica virens*) were also considered for suitability modelling. However, because there were limited or no historical data available, cumulative effects on these animals were not evaluated quantitatively.

Moose and elk are moderately abundant in both study areas and represent habitat generalists that are relatively tolerant of human disturbance. Woodland caribou and grizzly bear were selected because they are intolerant of human disturbance and generally require large areas of suitable habitat. The 'umbrella species' concept suggests that protection of habitat values and linkages for these large vertebrates will also provide protection for more than 90% of other species found in foothills areas (reviewed in Paquet and Hackman 1995).

3.1.3.2 Suitability Ratings

Habitat suitability is the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (Demarchi et al. 1990). Ratings of **habitat capability** have been developed for northeast B.C. by provincial sources. Capability is defined as the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999). Habitat suitability ratings are most commonly used for cumulative effects assessments (Hegmann et al. 1999).

Overall habitat suitability ratings were developed for 4 wildlife species (moose, caribou, elk, and grizzly bear) using forest cover data provided by the provincial government. Tree species dominance (primary, second, third, fourth) attributes identified 225 different combinations present in the Blueberry area. These were combined into 14 Biogeoclimatic units (site series) based on descriptions provided in DeLong (1988) and DeLong et al. (1990). Habitat units are summarized in Table 1 and depicted visually in Figure 3.

One of 7 age classes was then applied to each habitat unit using the Projected Age attribute included with forest cover data. Habitat suitability ratings for the 4 species were then applied for each Biogeoclimatic unit and age class as shown in Table 2. A four-class suitability rating system (High, Moderate, Low, Nil) appropriate for an intermediate level of knowledge was adopted (RIC 1999). Habitat suitability ratings were based on those developed for the Westcoast Energy Inc. Grizzly Valley Expansion Project (WEI 1994).

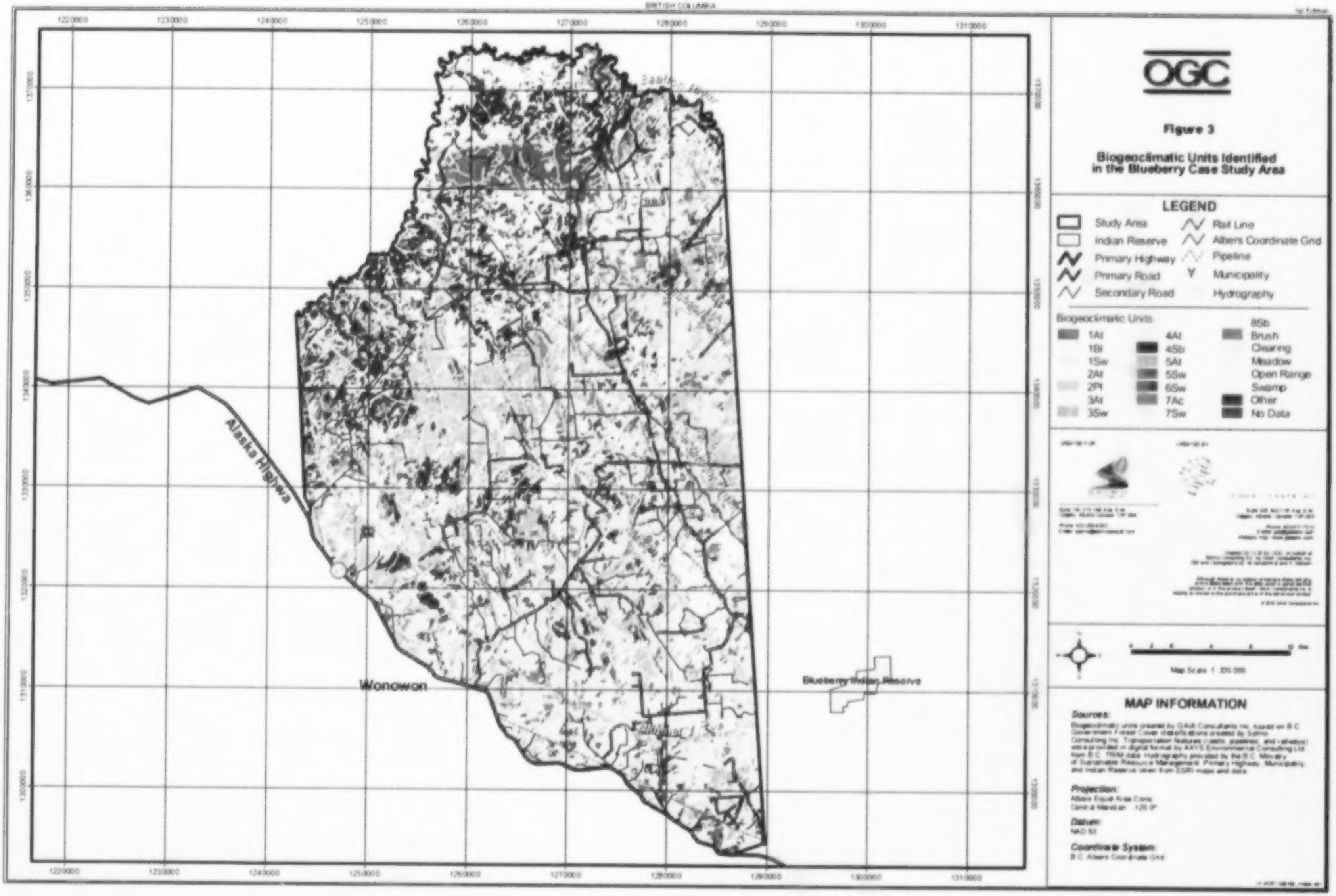
Table 1. Habitat Unit Area Summary for the Blueberry Case Study area.

BioGeoclimatic Unit	**Area (ha)**								**% of Study Area**
	Forest Seral Stage (age in years)							**Total**	
BSBW Unit	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**		
1At	204.43	75.84	102.53	1165.26	2709.33	1271.81	0.00	5529.20	2.0
1Sw	3118.45	8706.31	1928.18	8915.99	14267.49	25255.3	265.88	62457.60	23.2
2Pl	279.77	394.86	645.18	9056.48	2183.78	3026.66	287.59	15874.32	5.9
3At	207.12	1124.53	1925.94	8453.87	10195.23	3316.94	0.00	25223.63	9.4
3Sw	160.59	1423.73	634.75	13524.41	2639.26	4853.38	37.5	23273.62	8.6
4At	0.00	35.82	144.31	760.42	1004.70	507.83	0.00	2453.08	0.9
4Sb	1.36	521.94	869.63	5623.13	13090.86	15484.83	734.54	36326.29	13.5
5At	27.11	254.71	62.81	1164.54	229.16	73.19	0.00	1811.52	0.7
5Sw	0.00	14.03	0.00	0.00	5.96	2.66	0.00	22.65	0.0
6Sw	1883.00	726.39	111.31	770.06	1369.30	1796.45	395.22	7051.73	2.6
7Ac	0.00	0.00	0.00	0.00	28.65	48.79	0.00	77.44	0.0
7Sw	0.00	0.00	9.13	235.40	783.77	1428.93	36.38	2493.61	0.9
8Sb	0.00	4.99	466.57	2545.52	11715.88	7835.24	707.42	23275.62	8.6
Non-Specified									
Brush	28886.68	0.00	0.00	0.00	0.00	0.00	0.00	28886.68	10.7
Clearing	11450.80	0.00	0.00	0.00	0.00	0.00	0.00	11450.80	4.2
Meadow	18.92	0.00	0.00	0.00	0.00	0.00	0.00	18.92	0.0
Open Range	901.34	0.00	0.00	0.00	0.00	0.00	0.00	901.43	0.3
Other	2355.80	0.00	0.00	0.00	0.00	0.00	0.00	2355.80	0.9
Swamp	599.06	0.00	0.00	0.00	0.00	0.00	0.00	599.06	0.2
No Data	5956.74	0.00	0.00	0.00	0.00	0.00	0.00	5956.74	2.2
Total	56073.40	13453.53	7650.71	61615.19	61831.50	65905.18	2464.53	268994.04	
% of study area	20.84	5.00	2.84	22.90	22.99	24.50	0.92	100.0	100.0

OGC

Figure 3

Biogeoclimatic Units Identified in the Blueberry Case Study Area



MAP INFORMATION

Sources:
Biogeoclimatic units created by GAIA Consultants Inc. based on B.C. Government Forest Cover classifications created by Salmo Consulting Inc. Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. Hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality and Indian Reserve taken from ESRI maps and data.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

Table 2. Wildlife suitability ratings used in the Blueberry Case Study area.

BioGeoclimatic Unit	Moose							Grizzly Bear						
	Forest Seral Stage (age in years)							Forest Seral Stage (age in years)						
BSBW Unit	0-5	6-15	16-25	26-40	41-80	81-140	141+	0-5	6-15	16-25	26-40	41-80	81-140	141+
1At		High	High	Mod.	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
1Sw		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.		Low	Low	Low	Mod.	Mod.	Mod.
2At		Low	Mod.	Mod.	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
2Pl		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Low	Low
3At		High	High	High	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
3Sw		Low	Mod.	Mod.	Mod.	Low	Low		Low	Low	Low	Mod.	Mod.	Mod.
4At		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
4Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
5At		High	High	High	Mod.	Mod.	Mod.		Mod.	Mod.	Low	Low	Low	Low
5Sw		Low	Mod.	Mod.	Mod.	Mod.	Mod.		Mod.	Mod.	Low	Low	Low	Low
6Sw		Low	Mod.	Mod.	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Low	Low
7Ac		High	High	Mod.	Mod.	Low	Low		High	High	High	High	High	High
7Sw		Mod.	Mod.	Low	Low	Low	Low		Mod.	Mod.	Mod.	Low	Low	Low
8Sb			Mod.	Mod.	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
Brush	Mod.							Low						
Clearing	Low							Low						
Meadow	Low							Mod.						
Open Range	Low							Low						
Other	Nil							Nil						
Swamp	Mod.							Nil						

Table 2. Wildlife suitability ratings used in the Blueberry Case Study area (cont'd).

BioGeoclimatic Unit	Caribou							Elk						
	Forest Seral Stage (age in years)							Forest Seral Stage (age in years)						
BSBW Unit	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**
1At		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
1Sw		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
2At		Low	Low	Low	Mod.	Mod.	Mod.		Mod.	Mod.	Low	Low	Low	Low
2Pl		Low	Low	Low	Mod.	Mod.	High		Low	Low	Low	Low	Low	Low
3At		Nil	Nil	Nil	Nil	Nil	Nil		High	High	Mod.	Mod.	Mod.	Mod.
3Sw		Low	Low	Low	Low	Mod.	Mod.		Low	Mod.	Low	Low	Low	Low
4At		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
4Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
5At		Low	Low	Low	Low	Low	Low		High	High	Mod.	Mod.	Mod.	Mod.
5Sw		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Mod.	Low	Low	Low
6Sw		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
7Ac		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Low	Low
7Sw		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Low	Low
8Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
Brush	Nil							Low						
Clearing	Nil							Low						
Meadow	Nil							Mod.						
Open Range	Nil							Low						
Other	Nil							Nil						
Swamp	Nil							Nil						

Limited information on Non-Forest and Non-Productive Forest Units was provided with the forest cover data, and these units assumed to be 0 to 5 years (age class 1). Habitat suitability ratings were applied for Brush (defined as Non-Commercial, Non-Productive, Non-Productive Brush, and Non-Commercial Brush types), Clearing, Meadow, Open Range, and Swamp types. Other Non-Forest and Non-Productive Forest types, including Clay Bank, Gravel Bar, Lake, River, and Urban/Roads were assumed to have Nil suitability for all species (Table 2).

Trends in the availability of high and moderate suitability habitat were estimated for each species by RMZ. This was done by using the land use layer developed for each time period to calculate the area affected by direct disturbance.

Trends in the availability of relatively undisturbed 'core' habitat were also estimated in a similar manner. A zone of influence (GIS buffer) of 500 m was applied to all potentially 'high use features' (roads, trails, pipelines, railway lines, wellsites, communities, and clearings) to represent the area where reduced habitat effectiveness could occur. Residual core areas with high and moderate suitability were then calculated for each species by RMZ.

Use of a 500 m wide zone of influence for most features is considered to be conservative because avoidance is generally related to the level of activity rather than the features themselves (Mattson 1993; Dyer 1999; Gibeau 2000). Core area analyses undertaken for grizzly bears in Alberta have applied a 500 m zone of influence to high use features only (>100 parties per month; Gibeau et al. 1996; ESGBP 1998; Kansas and Collister 1999; Gibeau 2000). Studies conducted in the Alberta foothills show that off-road vehicle use of cutlines, pipelines, and old resource roads are generally lower than previously estimated (CRC 1999). In a 1,200 km^2 area southeast of Hinton, less than 40% of roads and only 3% of trails were classified as high use (average greater than 20+ vehicle parties per week). Most cutlines, old forestry and petroleum roads, and utility corridors averaged less than one vehicle pass per week (classified as no use for grizzly bear habitat effectiveness purposes; Kansas and Collister 1999; Salmo unpub. data). Given the comparatively low population density in the Fort St. John region, human use of most cutlines, pipeline rights-of-way, and old resource road is expected to be similar or lower in the Blueberry Case Study area.

3.1.4 Land Use Indices

Suitable cumulative effects indices and thresholds used elsewhere were tested using information obtained from the historical data review.

3.1.4.1 Access Density

Access density trends were calculated for each type of linear feature (primary roads, secondary roads, truck trails, pipelines, rail lines, cutlines) using the land use layer developed for each time period. Access density can vary dramatically within a relatively small area, so independent estimates were calculated using a 'moving window' comprised of a 1 km by 1 km grid. Basic statistical estimates (range and average) of access density were generated for each RMZ and subwatershed. Total road and trail density was also calculated for combined primary roads, secondary roads, and truck trails.

3.1.4.2 Cleared/Disturbed Area

Total cleared or disturbed area was selected as a numerical index of terrestrial habitat availability and fragmentation of the forest land base. Total cleared or disturbed area was calculated for all linear features using specified right-of-way widths: roads and utility corridors (20 m); truck trails and cutlines (8 m). Wellsites were assumed to average 1.5 ha in size and the size of other clearings was obtained from readily available data sources. Facilities and roads were identified from TRIM digital files or historical aerial photographs. Cleared/disturbed area estimates were also calculated by RMZ and subwatershed for comparative purposes.

3.1.4.3 Edge and Core Area

Edge and core area were calculated to provide complementary analyses of disturbance-influenced and relatively undisturbed areas, respectively. For comparative purposes, these estimates were derived for each RMZ, subwatershed, and time period.

Total edge area was calculated by applying an assigned 'buffer' on each side of linear features and around cleared areas. The area within the edge buffer was then calculated for each time period, RMZ, and subwatershed. Edge width was assigned based on feature size and assumed human use intensity. Primary and secondary roads, wellsites, and communities were assumed to be 'high use features' and were buffered by 500 m. Truck trails, pipelines, railway lines, and clearings were considered to be 'low use' features and were buffered by 250 m. Cutlines were considered to be 'no use' features and were not buffered.

Core areas were identified as those areas greater than 500 m from disturbance features (including primary and secondary roads, truck trails, pipelines, railway lines, wellsites, petroleum and industrial facilities, residences, communities, and unspecified clearings). As noted previously, this is assumed to provide a conservative (i.e., worst-case) estimate. Core area sizes were compared with minimum home range size or established core area thresholds to assess their suitability for specific species.

3.1.4.4 Stream Crossing Index

A 'stream crossing index', calculated as the number of crossings per km of stream, was used as a numerical indicator of potential aquatic disturbance. The watercourse network was based on digital TRIM II data. A stream crossing index was calculated independently for each linear feature and for combined roads, truck trails, and utility corridors for each time period by RMZ and subwatershed. For comparative purposes, stream index values were also calculated using 1:50,000 hydrography data.

3.1.4.5 Riparian Roads

The total length of roads and truck trails within 100 m of a watercourse was determined for each RMZ and subwatershed using road and hydrographic data layers described above. This was then converted to a density measure (km/km^2) based on calculated RMZ or subwatershed area. For comparative purposes, stream index values were also calculated using 1:50,000 hydrography data.

3.1.4.6 Cleared Riparian Area

An estimate of riparian area cleared was calculated by multiplying specified right-of-way widths: roads and utility corridors (20 m); truck trails and cutlines (8 m) and a riparian zone width of 30 m (15 m on each bank) for each stream and lake (Chilibeck et al. 1992; Harper and Quigley 2000). Estimates were derived for each RMZ, subwatershed, and time period for comparative purposes. For comparative purposes, stream index values were also calculated using 1:50,000 hydrography data.

3.1.5 Future Scenarios

The A Landscape Cumulative Effects Simulator (ALCES) developed by Forem Technologies Ltd. (www.foremtech.com) was used to visualize the effect of past and future development in the Blueberry Case Study area. Historical development trends were projected over a 100 year period (1950 to 2050) to examine land use patterns, forest age and structure, and wildlife habitat effectiveness. The objective of this simulation was to evaluate the capabilities of the ALCES model to conduct strategic-level simulations of regional landscapes, to provide projections of the natural range of variability, and to compare results provided by ALCES and conventional cumulative effects assessment methods.

ALCES is a spatially proportional landscape simulator that integrates four sub-models (habitat availability, population, land use, and natural disturbance). It considers all land use activities likely to occur in the Blueberry Case Study area and is able to incorporate stochasticity. Its greatest strength is its ability to rapidly incorporate user-defined changes so that the effect of various development scenarios and management options on future habitat availability and populations can be visualized (Salmo et al. 2001).

Indicators used for this simulation were:

- moose Habitat Effectiveness Index (habitat quality on scale from 0 (no value in Case Study area) to 1 (entire Case Study area has high value)),
- woodland caribou Habitat Effectiveness Index (habitat quality on scale from 0 to 1)
- total anthropogenic footprint (ha) and edge (km/km^2),
- road and trail edge (km/km^2),
- average forest patch size (ha),

- average forest age (years),
- old growth forest (% of area), and
- merchantable forest in old growth (% of area).

3.1.5.1 Habitat Quality and Availability

The number of forest types that ALCES can consider is limited to nine, so Biogeoclimatic units described in Section 3.1.3.2 were modified to conform to ALCES seral stage and forest cover classifications. Terrestrial habitat types were: hardwood; mixedwood; white spruce; pine; black spruce; fens, bogs and marshes; low shrubland; tall shrubland; and moss/lichen. Aquatic habitat was classified into small, medium, and large lakes, and small, medium, and large watercourses.

Habitat conditions in 1950 were estimated by dissolving the current forest-cover TRIM-based land use information into forest cover types to approximate an undisturbed landscape. A representative forest age class structure was reconstructed using Monte Carlo simulations of fire events. This provided an initial undisturbed landscape for all simulations (the 'undisturbed 1950 landscape'). Habitat was 'grown' from this point forward based on this derived forest age class structure. To consider the effects of natural disturbance, fire regime was run as a constant 125 year cycle for softwood (coniferous or coniferous-dominated) and 100 year cycle for hardwood (deciduous or deciduous-dominated) forest as recommended by BCF and MELP (1999b). No insect mortality events were included.

Trends in woodland caribou and moose habitat availability, habitat quality and habitat effectiveness were evaluated. These provide a contrast between two ungulates with moderate and low ecological resilience. Moose are a habitat generalist with moderate reproductive potential and are relatively tolerant of human disturbance. Caribou are a habitat specialist with low reproductive potential and are comparatively intolerant of human disturbance. Random simulations of fire were also conducted to estimate the natural range of variability of moose and woodland caribou habitat availability, quality, and effectiveness in the Blueberry Case Study area. Each Monte Carlo simulation was run over a 100 year period beginning with an undisturbed 1950 landscape.

The modelling assumptions adopted for woodland caribou were those being used by biologists working with northern- and boreal-ecotypes in northwest Alberta. Moss/lichen habitat, and mature and old seral stages (>80 years) of coniferous forests were rated as the highest quality habitat; this is consistent with the ratings provided in Section 3.1.3.2. Disturbance buffers were applied to roads, trails, pipelines, wellsites, and cutblocks; these buffers are more conservative (i.e., larger) than buffers used in Case Study core and edge area analyses (Section 3.1.4.3).

Moose habitat suitability coefficients were based on the suitability ratings described in Section 3.1.3.2; they were modified by Forem to ensure consistency with seral stage and forest cover classifications of ALCES. Young to mature seral stages (<80 years) were rated as the highest quality habitat.

3.1.5.2 Historical Land Use

Land use types considered by ALCES were major (primary) roads, minor roads (secondary roads and truck trails), pipelines, cutlines, railway lines, wellsites, and agricultural clearings. These land use features were added to the undisturbed 1950 landscape in a spatially proportional manner. The land use footprint was then 'grown' using development rates calculated for the Blueberry Case Study area (see Section 3.2) to generate the correct current (year 2000) landscape composition.

The potential benefits of enhanced and restrictive environmental protection practices was also evaluated by comparing two 100 year simulations: one based on standard industry practices, and one incorporating a number of best practices (road and corridor harmonization, reduced wellsite size and seismic line width, multiple wells per site, immediate site revegetation, and increased clearcut size).

3.1.5.3 Future Land Use

Projections of future land use were provided for the period 2000 to 2050. The land use footprint was 'grown' based on trends quantified in the Case Study and added to the landscape in a spatially proportional manner. Three future energy development scenarios were simulated: low growth (1950 to 1998 average development rate); moderate growth (1970 to 1998 average development rate); and high growth (1970 to 1998 development rate plus 20%).

3.2 DEVELOPMENT TRENDS

Enhanced resource development is the primary land use objective in all of the Blueberry study area outside the Alaska Highway Corridor. Dominant land uses include petroleum exploration and development, agriculture, grazing, and forest harvest. All-weather and winter trails provide access to most of the area.

3.2.1 Petroleum Activity

The energy industry is the largest economic sector in northeast British Columbia. Petroleum activity increased in this region in the late 1940's and oil and gas exploration and development has continued cyclically since that time. Approximately 12,000 wells have been drilled in northeast British Columbia, resulting in the identification of over 1,700 oil and gas pools. On average, 288 wells have been drilled each year since 1960. Exploration activity has intensified in the last ten years, with an average of 539 wells per year (Figure 4).

Seismic activity records are available only since 1982, but activity over this 20 year period has also continued cyclically (Figure 5). Since 2000, the level of proposed seismic activity has been three times greater than the 1982 to 1999 average.

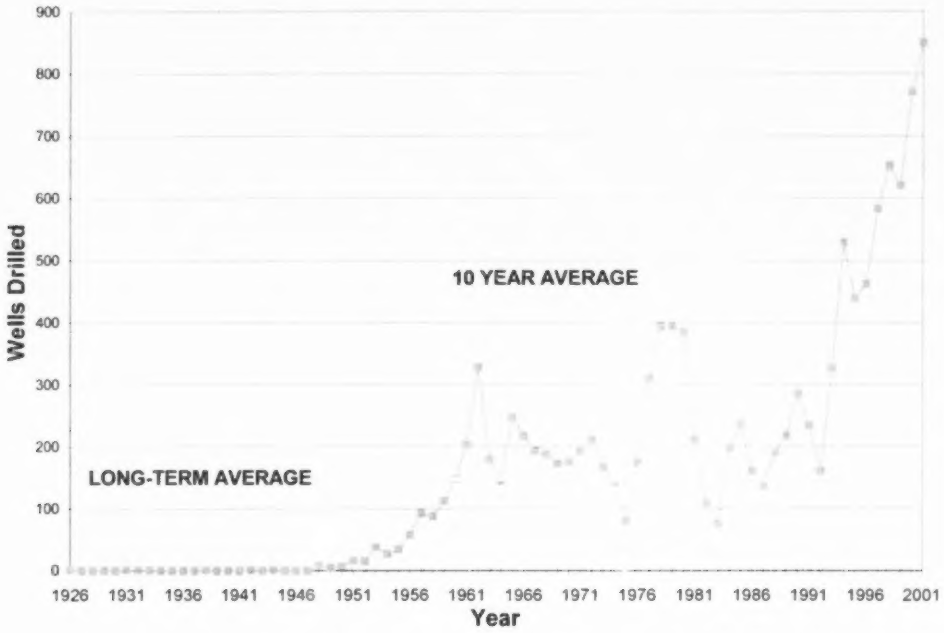


Figure 4. Annual wells drilled in northeast British Columbia, 1926 – 2001.

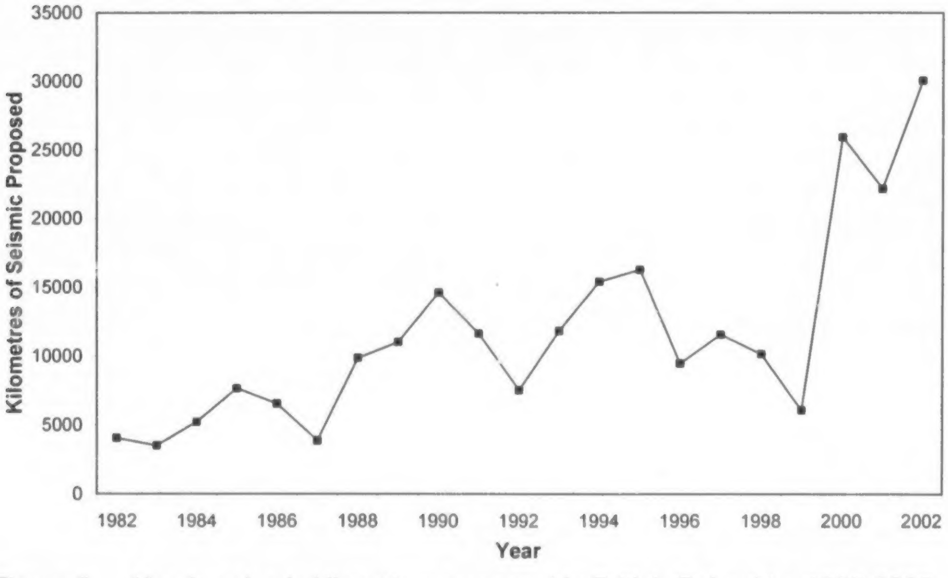


Figure 5. Yearly seismic kilometres proposed in British Columbia, 1982-2002.

Natural gas is processed at more than 20 small and large facilities located in the region, many of which recover sulphur and liquids. Oil and gas infrastructure and activity are concentrated in three development areas: Dawson Creek, Fort St. John, and Fort Nelson. The Blueberry Case Study area is located in the Fort St. John development area, which was developed first and has extensive production and infrastructure.

The Blueberry area was first developed in the early 1950's and currently has numerous active natural gas tenures and substantial natural gas infrastructure. Potential gas reserves are moderate to high. Table 3 summarizes the changes in oil and gas infrastructure that have occurred in the Blueberry study area since 1950.

On average, approximately 4 wells and 12 km of secondary roads, 50 km of truck trails, 125 km of cutlines, and 5 km of pipeline have been constructed each year since 1950 in the Blueberry area. Annual average construction rates for most features have increased since 1970 to approximately 9 wells, 65 km of trail trails, 135 km of cutlines, and 7 km of pipeline.

Historical oil and gas development activities and interviews with shipper representatives were used to forecast likely geophysical and field development activities associated with the Westcoast Energy Inc. Fort St. John Expansion Project proposed in 1994. Based on historical development patterns, 3 km of road and 2.6 km of pipeline have been associated with each well in the Fort St. John gas supply area. Predicted average annual future activity rates in the Blueberry area were 22 wells, 8 km of roads, 225 to 300 km of cutlines, and 4 km of pipeline (Salmo unpub. data). This forecast occurred during the early 1990's activity peak.

Table 3. Petroleum development trends in the Blueberry study area.

Feature	1950		1970		Current[2]	
	No. or km	Area (ha)	No. or km	Area (ha)	No. or km	Area (ha)
Secondary Roads[1]	111	222	375	750	700	1,399
Truck Trails	260	190	1,027	768	2,830	2,088
Wellsites	8	12	133	200	208	880
Cutlines	974	737	3,494	2,664	7,223	5,420
Pipelines	20	41	142	266	247	453
Total	-	1,202	-	4,648	-	10,240

[1] Includes secondary roads attributable to all economic sectors.

[2] Data are from the late 1990's.

The provincial government has recently announced plans to encourage oil and gas production in northeast British Columbia, with the goal of doubling production by, and likely overestimates current development rates.

3.2.2 Forest Harvest

Approximately 48% (2,250,000 ha) of the Fort St. John Forest District is considered to be productive forest, but slightly less than half of this productive forest area (1,060,000 ha) is available for timber harvesting under current management practices. Aspen, lodgepole pine, and white spruce are the dominant tree species available for harvesting within the region (MOF 2002).

The entire Blueberry Case Study area is within Pulpwood Agreement 12 (PA 12), apportioned to Fibreco (Slocan Forest Products; ARA and Keystone 1996). PA 12 covers most of the Fort St. John Timber Supply Area (FSJ TSA). The agreement specifies a deciduous Allowable Annual Cut (AAC) of 500,000 m^3, roughly 55% of the regional AAC of 915,000 m^3 (FSJ LRMP 1997). Rights to coniferous timber have been provided to Canadian Forest Products Ltd. (Canfor) under Forest Licence A18154. The AAC for this licence (704,793 m^3) represents 64% of the coniferous AAC in the FSJ TSA (1,100,000 m^3) and provides approximately 70% of Canfor's sawmill requirements.

The Blueberry study area contains valuable timber resources, and harvesting has been extensive in the Blueberry River drainage and upper Aitken Creek drainage since the mid 1950's. New forest plantations are well established on the old cutblocks. Deciduous and coniferous timber is present on both privately-owned and Crown lands (FSJ LRMP 1997). There is currently a small market for aspen species in the region, and only a very small portion of the deciduous AAC has been harvested. No deciduous harvest has occurred within PA 13 or the Blueberry area to date. Volumes logged and sold off private lands in the Agriculture Settlement RMZ increased in the mid-1990's in response to timber price increases (ARA and Keystone 1996). Canfor plans to continue to harvest timber from clearcut blocks in the Blueberry River and upper Aitken Creek drainages. Most existing and proposed activity is concentrated near the Tommy Lake Forest Service Road and Alaska Highway.

Forest clearing trends in the Blueberry study area are summarized in Table 4. The average harvest rate over the last 50 years is estimated to be 224 ha per year in the Alaska Highway and Jedney RMZs.

Plans are underway to construct a mill to produce oriented strand board from aspen, and harvest of deciduous timber will likely occur within PA 13 within the next 5 years (BCF 2001). Projections suggest that the current regional Annual Allowable Cut for deciduous stands can be maintained for 30 years, after which it would have to decrease by 10% per decade until the long-term harvest level of 632,000 m^3/yr is reached (MOF 2002).

Table 4. Forest clearing trends in the Blueberry study area (ha).

Feature	1950	1970	Current[2]
Clearings[1]	218	1,927	10,976

[1] Includes undefined clearings in the Jedney and Alaska Highway RMZs

[2] Data are from the late 1990's

3.2.3 Agricultural Development

Agriculture has a long history in the Fort St. John area and cattle ranching is now the leading farm activity in this region. Livestock production steadily expanded, especially in recent years, and large areas of parkland have been converted to grazing and forage production.

Agricultural clearing trends in the Blueberry study area are summarized in Table 5. The average forest conversion rate over the last 50 years is estimated to be 370 ha per year in the Agriculture Settlement and Grazing Reserve RMZs.

Table 5. Agricultural clearing trends in the Blueberry study area (ha).

Feature	1950	1970	Current[2]
Clearings[1]	0	5,695	17,783

[1] Includes undefined clearings in the Agriculture Settlement and Grazing Reserve RMZs

[2] Data are from the late 1990's

3.2.4 Land Use Trends

3.2.4.1 Landscape Disturbance

Current infrastructure in the Blueberry Case Study area is shown on Figure 2, included previously in Section 2.1. Charts depicting trends in disturbance features and residual core areas calculated for the Blueberry case study area are provided below for each landscape index. Data used to generate these charts are summarized in Appendix A of this report.

3.2.4.2 Access Density

Access density plots for the Blueberry study area are provided by RMZ in Figure 6 and by subwatershed in Figure 7. Railway and pipeline densities have been uniformly low and are not presented. In 1950, linear features in the Blueberry study area included approximately 271 km of primary and secondary roads, 261 km of truck trails, 20 km of pipeline right-of-way, and 974 km of cutlines. At this point in time, there were no railway lines. This equates to average corridor densities of 0.10 km/km^2 of roads, 0.09 km/km^2 of truck trails, 0.01 km/km^2 of utility corridors (pipelines and railway lines), and 0.34

km/km^2 of cutlines. Median values for all corridor types are 0, indicating that more than half of the Blueberry study area remained undisturbed at this point in time.

By 1970, the Blueberry study area contained 733 km of roads, 1,027 km of truck trails, 142 km of pipelines, and 3,494 km of cutlines. Approximately 63 km of railway line had been constructed. This equates to an average corridor density of 0.26 km/km^2 of roads, 0.36 km/km^2 of truck trails, 0.07 km/km^2 of utility corridors and 1.23 km/km^2 of cutlines. By 1970, the median value for all corridor types remained at 0, except for cutlines, which increased to 1. This indicates that seismic programs covered more than half the study area by 1970.

Most recently, combined linear features in the Blueberry study area include 1,729 km of roads, 2,830 km of truck trails, 247 km of pipelines, and 7,223 km of cutlines. Rail line density was unchanged. Expressed as average corridor density, the Blueberry area now supports 0.61 km/km^2 of roads, 1.00 km/km^2 of truck trails, 0.11 km/km^2 of utility corridors, and 2.54 km/km^2 of cutlines. Median cutlines density is 2.36 km/km^2 and median truck trail density is 0.66 km/km^2; median values for all other corridor types remain at 0.

3.2.4.3 Generalized Road Density Ratings

Quigley et al. (1996) established categories to rank road density in the Interior Columbia Basin of the Pacific Northwest. Table 6 summarizes trends in combined road and truck trail density within the Blueberry study area using these categories. Average overall road density in the study area increased from Low (0.19 km/km^2) in 1950 to Moderate (0.62 km/km^2) in 1970 to High (1.61 km/km^2) in the late 1990's.

Table 6. Road and trail density trends in the Blueberry Case Study area.

Category	Road Density (km/km^2)	Percent of Study Area		
		1950	1970	Current*
Very Low	0.0 to 0.06	78.0	48.0	19.7
Low	>0.06 to 0.4	6.4	10.7	10.1
Moderate	>0.4 to 1.1	10.3	19.2	19.7
High	>1.1 to 2.9	4.9	19.3	34.4
Extremely High	>2.9	0.4	2.8	16.1

* Data are from the late 1990s

In 1950, road and truck trail access density was Very Low in most of the Blueberry study area, and large areas had little or no access. Highest road density occurred in the area immediately adjacent to the Alaska Highway (Alaska Highway RMZ and Lower Peace River subwatershed).

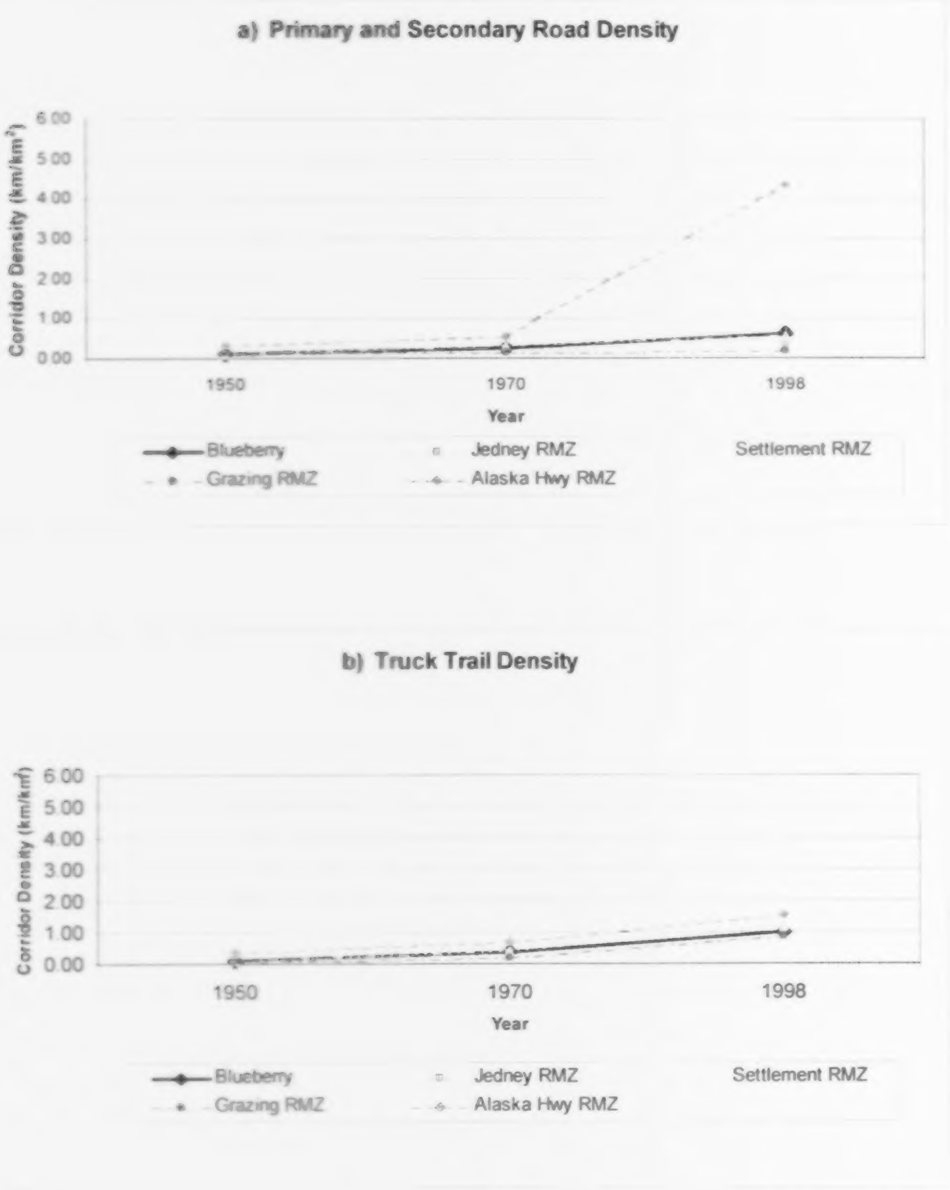


Figure 6. Access density trends in Blueberry study area RMZs.

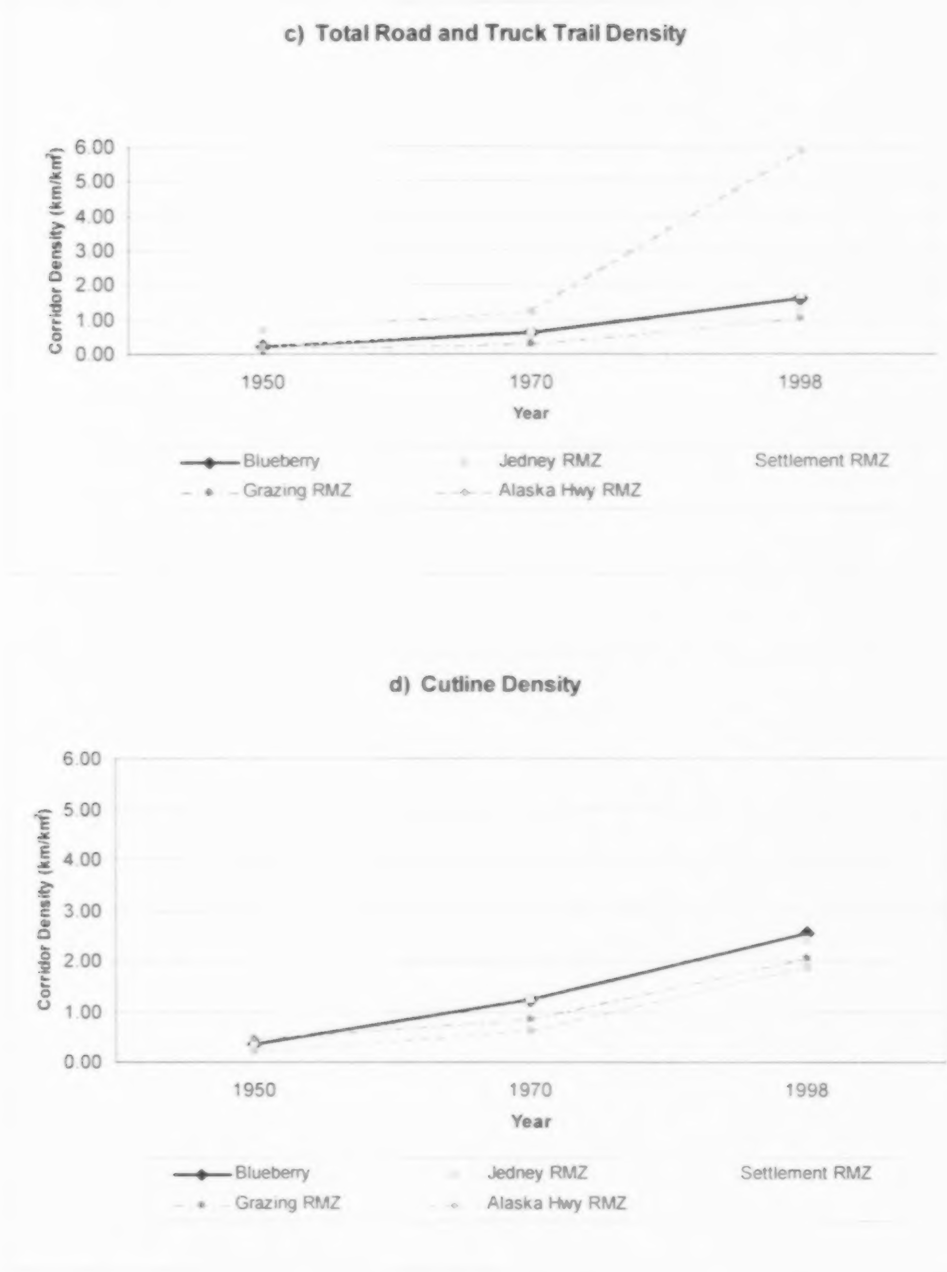
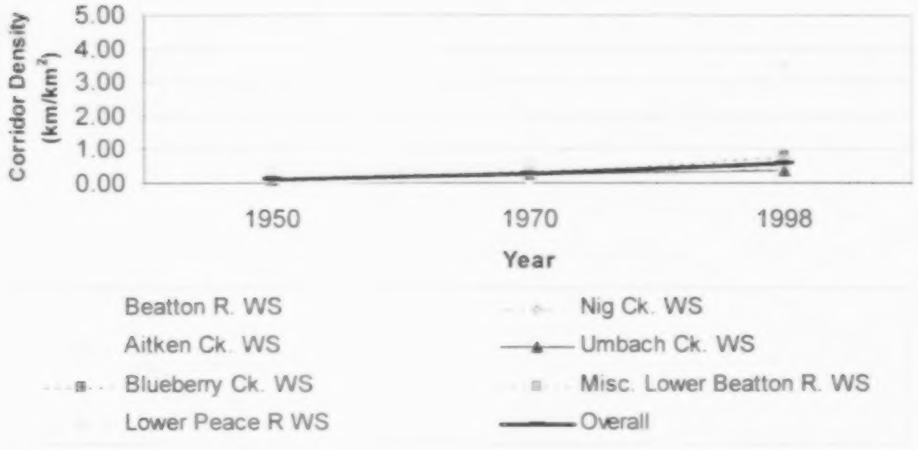
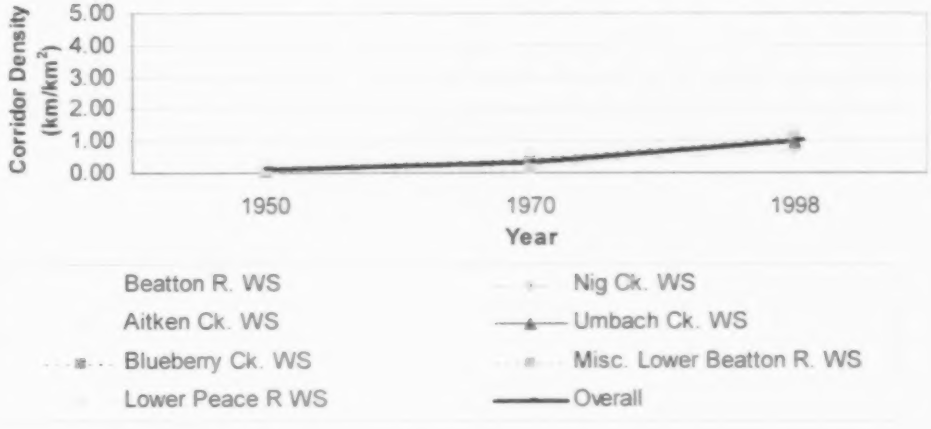


Figure 6. Access density trends in Blueberry study area RMZs (cont'd.).

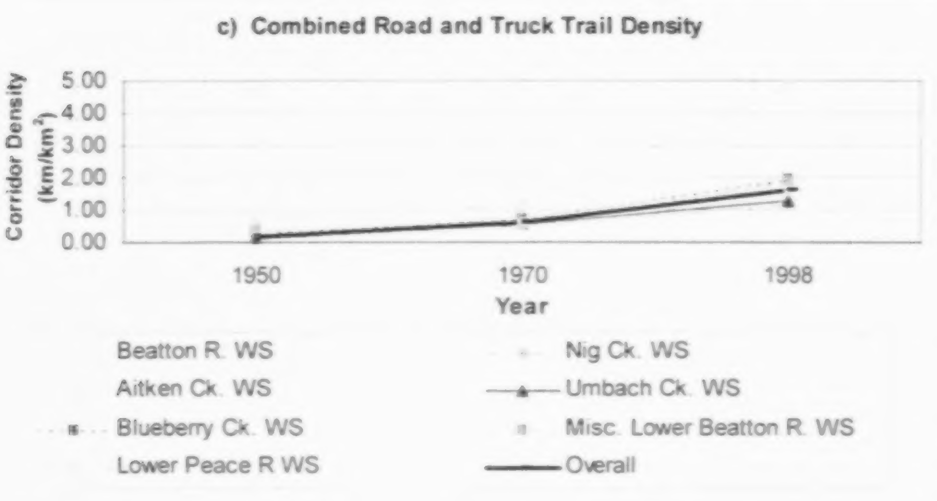


a) Primary and Secondary Road Density



b) Truck Trail Density

Figure 7. Access density trends in Blueberry study area subwatersheds.



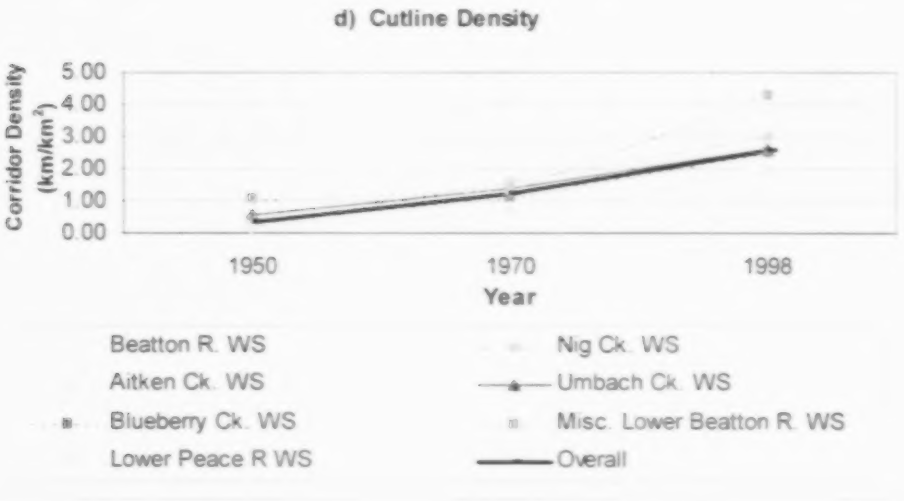


Figure 7. Access density trends in Blueberry study area subwatersheds (cont'd).

Road density had increased over one-third of the study area by 1970, but most of the Blueberry area was still classified as Moderate or lower. The largest increases occurred in the Agricultural Settlement and Alaska Highway RMZs and the Aitken Creek and Lower Peace subwatersheds.

Combined road and trail density increased dramatically between 1970 and the late 1990's. Areas with little or no road access currently represent less than 20% of the study area, and approximately half of the study area has high or extremely high road densities. Most road construction continued to occur in the Alaska Highway and Agricultural Settlement RMZs. During this period, very large increases in road density occurred in the Lower Peace River, Beatton River, and Blueberry Creek subwatersheds (Figures 6 and 7; Appendix A).

BCF and BCE (1995b) identified the following aquatic hazard levels for road density:

Low: 0 to 0.9 km/km^2

Medium: >0.9 to 1.72 km/km^2

High: >1.72 km/km^2

Using these criteria, the aquatic hazard rating in 1950 was Low over about 70% of the study area, and High over less than 12% of the area. By 1970, Low, Medium, and High hazard levels were present over 60%, 17%, and 23%, respectively of the overall Blueberry study area. Currently, about 17% of the Blueberry study area has a Low aquatic hazard rating, 10% has a Medium aquatic hazard rating, and 73% has a High aquatic hazard rating. The Beatton River, Nig Creek, Aitken Creek, and Umbach Creek subwatersheds currently have a Medium aquatic hazard; other subwatersheds have a High aquatic hazard rating (Figures 6 and 7; Appendix A).

Watershed road densities greater than 2.5 km/km^2 increased sediment yield and affected downstream spawning habitat in a forested coastal watershed in the Pacific Northwest (Cederholm et al. 1981). In 1950, less than 1% of the Blueberry area exceeded this threshold. Road and trail densities exceeded 2.5 km/km^2 over almost 5% of the area in 1970, and currently exceed this threshold over 20% of the study area. At the local scale, only the Lower Peace River subwatershed currently exceeds this road density threshold (Figure 7). In the Blueberry Case Study area, the Lower Peace subwatershed comprises a very small area immediately adjacent to the Alaska Highway. Landscape and watershed indicators calculated for this area are not representative of the total drainage, and will be excluded from further analysis.

3.2.4.4 Species-Specific Road Density Thresholds

Road densities greater than 0.6 km/km^2 may affect habitat usage by wolves and elk, although these effects can be mitigated by the presence of visual barriers and adjacent unroaded areas (Lyon 1983,1984; Thiel 1985; Edge and Marcum 1991; Mech 1989; Rowland et al. 2000). Areas selected by grizzly bears in northern Montana and southeast

British Columbia had average road densities of 0.6 to 0.68 km/km^2 (Mace et al. 1996; McLellan and Hovey 2001). Road densities greater than 1.2 km/km^2 may affect habitat usage by grizzly bear (Mace and Manley 1993) and areas with road densities greater than 6 km/km^2 do not appear to support grizzly bears (Mace et al. 1996). Bull trout populations were seven times more likely to be strong in subwatersheds with road densities less than 1.55 km/km^2 in the Columbia and Klamath river basins in the Pacific Northwest (Rieman et al. 1997).

Figure 8 presents current combined road and truck trail density in the Blueberry Case Study area in comparison to 0.6 and 1.2 km/km^2 thresholds. The 0.6 km/km^2 road density threshold was exceeded on nearly 13% of the Blueberry study area in 1950, and 36% of the area in 1970. Road density currently exceeds 0.6 km/km^2 on approximately 65% of the Blueberry study area (Figure 8). This threshold is exceeded in each RMZ and watershed (Appendix A), which suggests that habitat usage by sensitive species has been affected throughout the case study area.

The 1.2 km/km^2 road density threshold was exceeded on less than 5% of the Blueberry study area in 1950, and 20% of the area in 1970. At the local scale, the road density threshold was exceeded in the Alaska Highway Corridor RMZ in 1950. By 1970 it was also exceeded in the Agriculture Settlement Area RMZ. Road density currently exceeds 1.2 km/km^2 on approximately 48% of the Blueberry study area (Figure 8). This threshold is currently exceeded in all RMZs and subwatersheds (Appendix A). This suggests that grizzly bears are likely to avoid roaded portions of the Blueberry study area on a seasonal, daily, or continuous basis.

In 1950 and 1970, respectively 98% and 87% of the Blueberry study area was within the 1.55 km/km^2 threshold. Under current conditions, this threshold is exceeded in the overall Blueberry area and the Beatton River, Aitken Creek, Blueberry Creek, and Lower Peace River subwatersheds. This suggests that salmonid populations are most likely to be secure in the Nig and Umbach Creek subwatersheds.

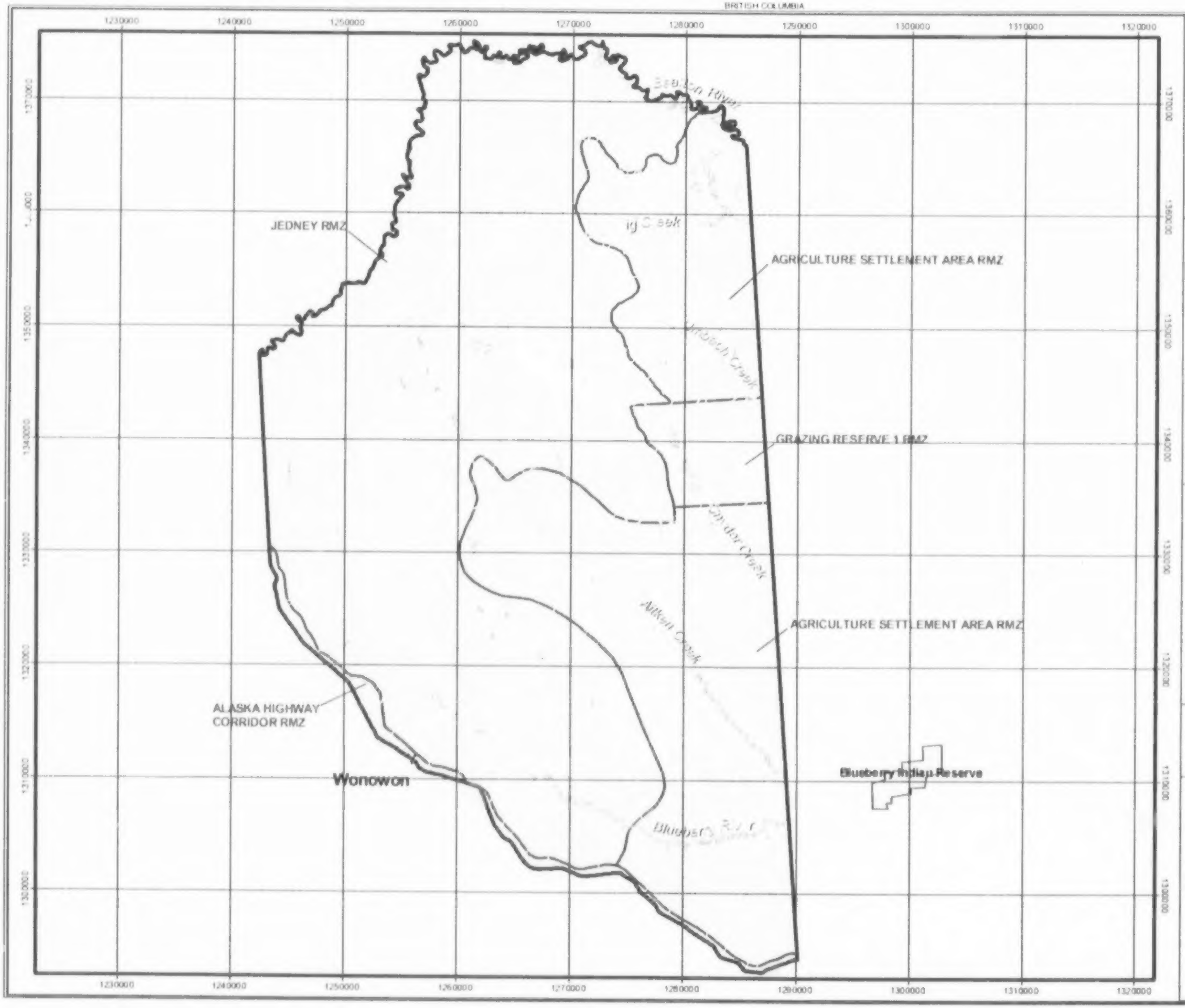
The 6 km/km^2 road density threshold was exceeded on less than 0.1% of the Blueberry study area in 1950, and 0.1% of the area in 1970. Road density currently exceeds 6 km/km^2 on approximately 2% of the Blueberry study area, which suggests that grizzly bears have been excluded from small portion of this case study area.

3.2.4.5 Cleared/Disturbed Area

Overall clearing trends for the Blueberry Case Study area are summarized by RMZ in Figure 9 and by subwatershed in Figure 10 based on data provided in Appendix A.

In 1950, less than 1% of the study area was cleared for combined industrial, residential, agricultural, and infrastructure development. Cutlines and roads were by far the largest disturbance sources. Combined disturbance was highest in the Alaska Highway Corridor and Agriculture/Settlement RMZs and the Lower Beatton River and Aitken Creek subwatersheds.

1st Edition



OGC

Figure 8
Current Combined Road and Truck Trail Density in the Blueberry Case Study Area

LEGEND

▭	Study Area	Access Density
▭	RMZ Boundary	<0.60 km / km²
▭	Indian Reserve	0.60 - 1.20 km / km²
Y	Municipality	>1.20 km / km²
	Hydrography	
/\/	Albers Coordinate Grid	

4 2 0 4 8 12 Km

Map Scale 1: 335 000

MAP INFORMATION

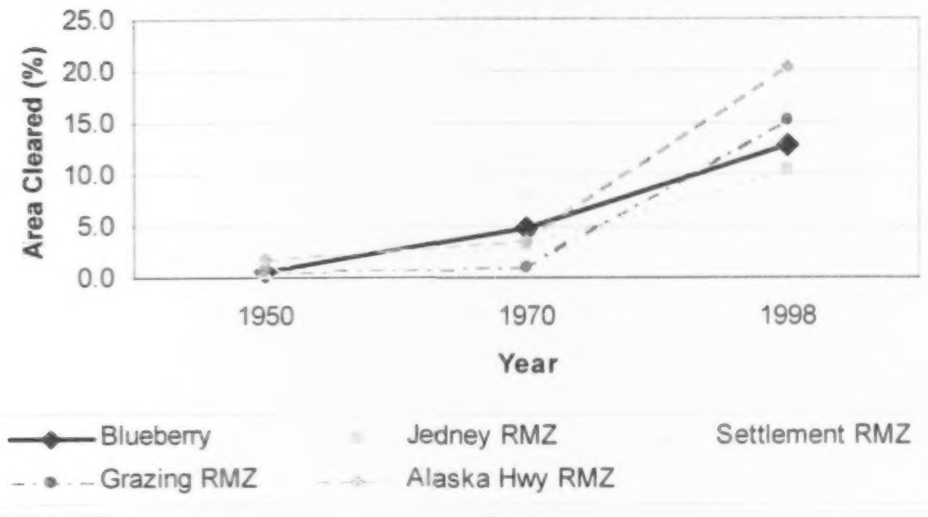
Sources:
RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Indian Reserve and Municipality taken from ESRI maps and data. Access Density Grid created by GAIA Consultants Inc. as part of the CEA analysis performed using TRIM data

Projection:
Albers Equal Area Conic
Central Meridian: 126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

a) Total Cleared Area - All Disturbances



b) Cleared Area - Other Clearings

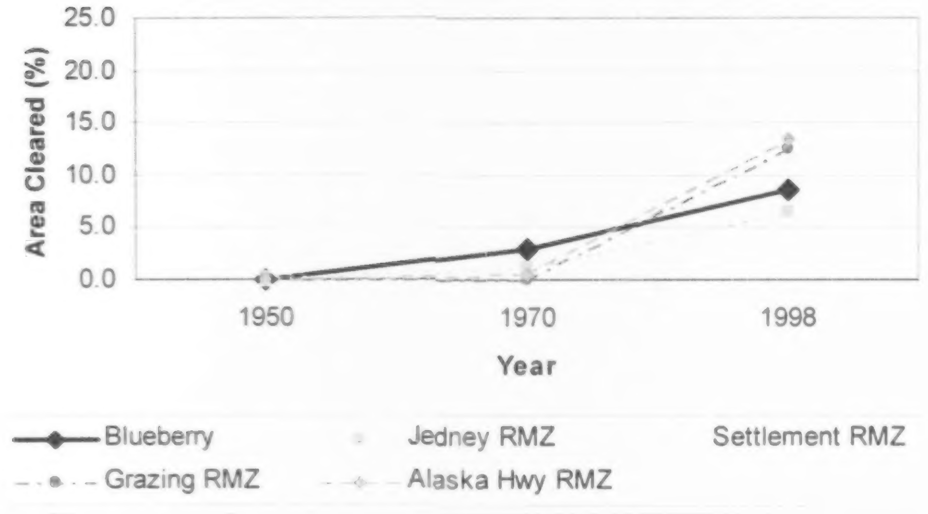
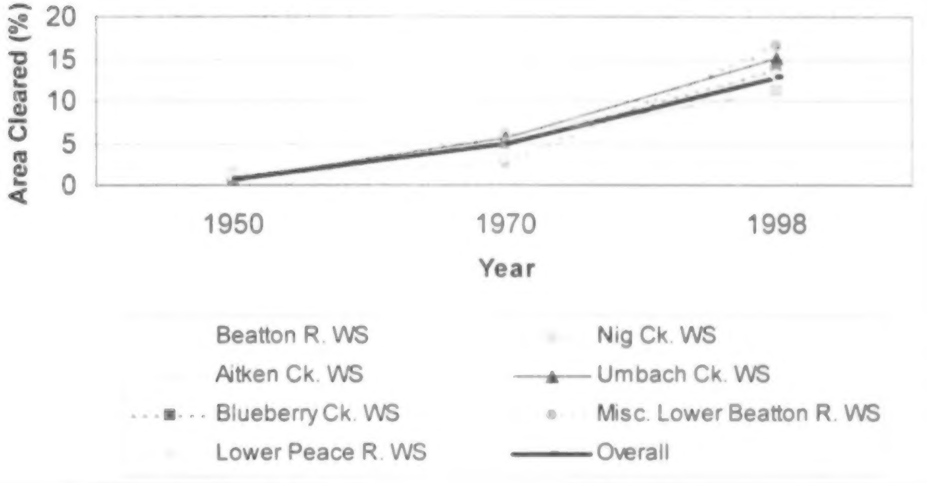


Figure 9. Trends in forest clearing in Blueberry study area RMZs.

a) Total Cleared Area - All Disturbances



b) Cleared Area - Other Clearings

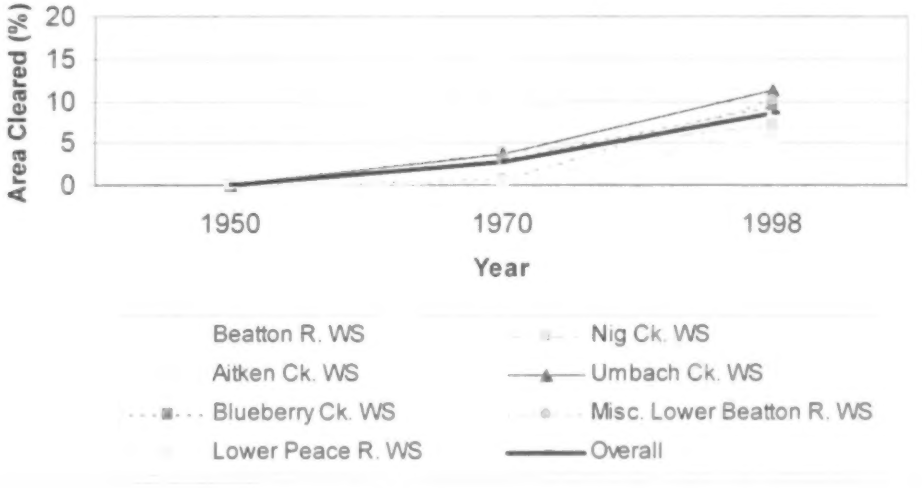
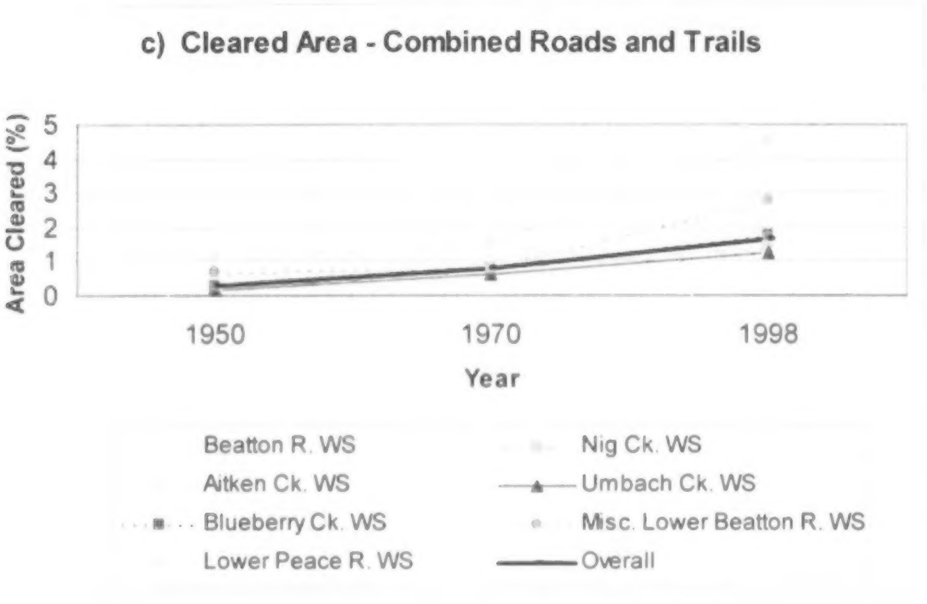
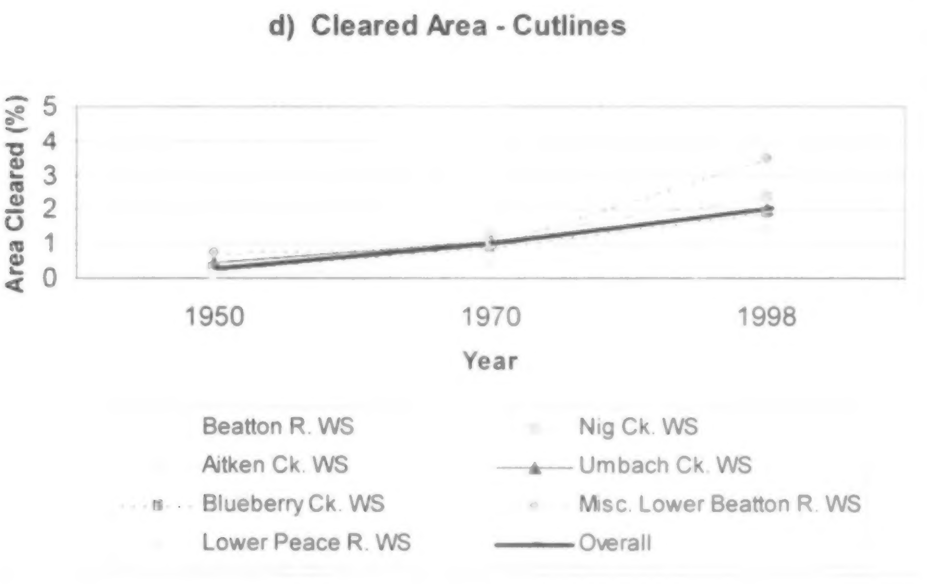


Figure 10. Trends in forest clearing in Blueberry study area subwatersheds.



c) Cleared Area - Combined Roads and Trails



d) Cleared Area - Cutlines

Figure 10. Trends in forest clearing in Blueberry study area subwatersheds (cont'd).

In 1970, almost 5% of the study area was cleared, but clearings associated with industrial, agricultural, and residential development had become the largest disturbance source. Combined disturbance remained highest in the Agriculture Settlement RMZ, and was also concentrated in the Nig Creek, Umbach Creek, and Aitken Creek subwatersheds.

Average clearing rates increased after 1970 as development of the Blueberry area intensified. Approximately 13% of the Blueberry study area is currently cleared, primarily by industrial, agricultural, and residential development. Cleared area is highest in the Grazing Reserve RMZ and similar in other RMZs. Disturbed areas cover more than 15% of the Lower Beatton River and Umbach Creek subwatersheds and 13% or more of the Blueberry Creek, Aitken Creek, and Lower Peace River subwatersheds.

Generalized clearing thresholds have been applied for landscape-level evaluations of cumulative effects on terrestrial habitat; species-specific evaluations usually consider the quality of available habitat as well.

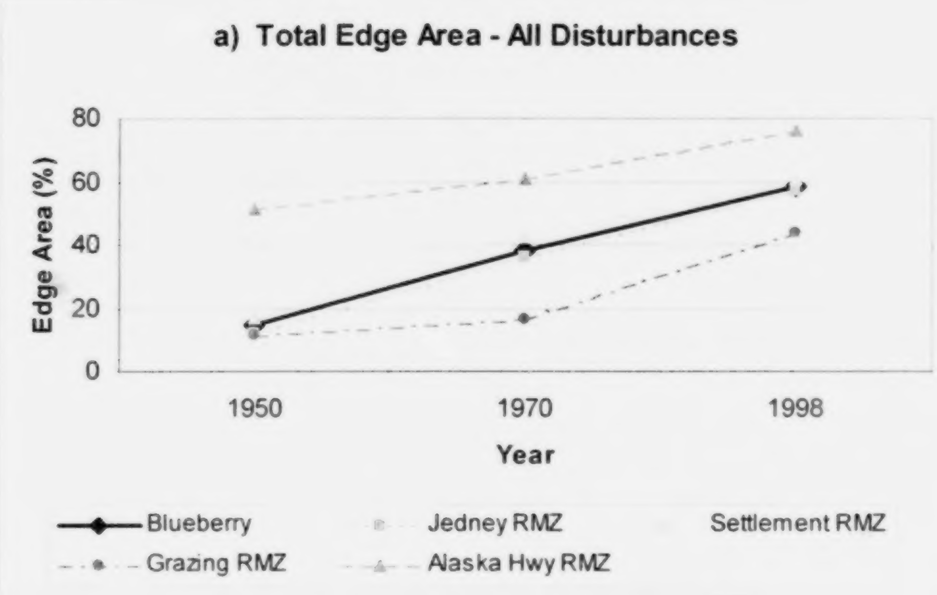
Theoretical models suggest that habitat specialists may be affected when available habitat occupies less than 40% of the landscape, whereas habitat generalists may be affected when suitable habitat occupies less than 20% to 35% of the landscape (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995). Marten home ranges in black spruce forest in Quebec usually contained more than 40 to 50% uncut forest (Potvin et al. 2000). Maintenance of more than 50% to 75% forest cover in areas greater than 9 to 10 km^2 (Hargis et al. 1999; Potvin et al. 2000) has been recommended to protect marten. At a landscape scale, current clearing in the Blueberry study area is well within theoretical criteria for habitat specialists.

Available literature indicates that detectable effects on streamflow occur when more than 20% of a watershed is cleared in less than 10 years (McGurk and Fong 1995). Risk of cumulative effects is elevated where cleared area (expressed as equivalent clearcut area) exceeds 18%, and greatly elevated where cleared area exceeds 36% (BCF and BCE 1995b). Cleared area in the overall Blueberry study area and subwatersheds has not exceeded these thresholds.

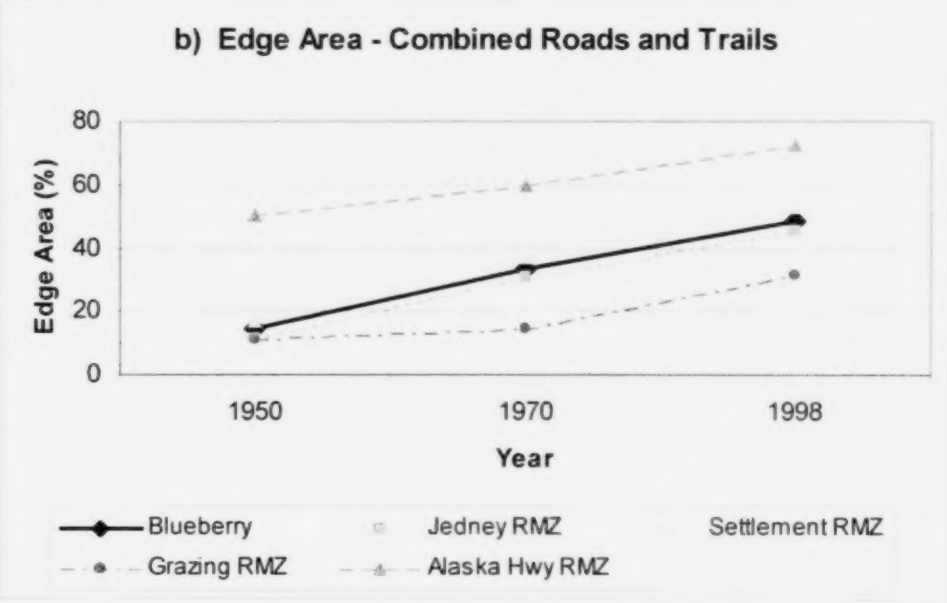
Sediment accumulation increases when road area is greater than 2.5% of basin area (Cederholm et al. 1981). Combined road and truck trail areas exceed this threshold in the Lower Beatton River subwatershed, which suggests that sediment yield has likely increased in portions of the Blueberry study area.

3.2.4.6 Edge Area

Trends in combined edge areas adjacent to low and high use features are summarized by RMZ in Figure 11 and by subwatershed in Figure 12. Complete data are provided in Appendix A.

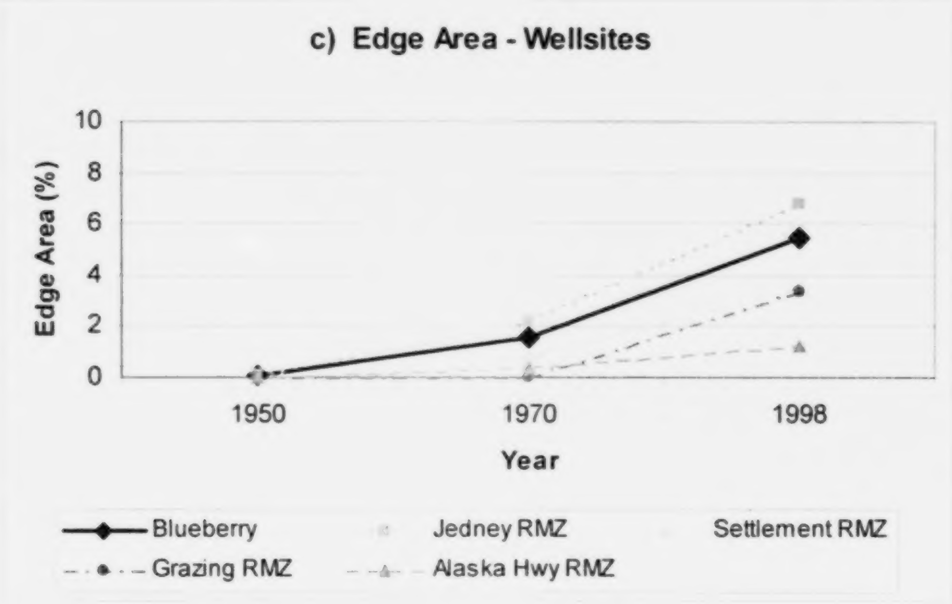


a) Total Edge Area - All Disturbances



b) Edge Area - Combined Roads and Trails

Figure 11. Trends in edge area in Blueberry study area RMZs.



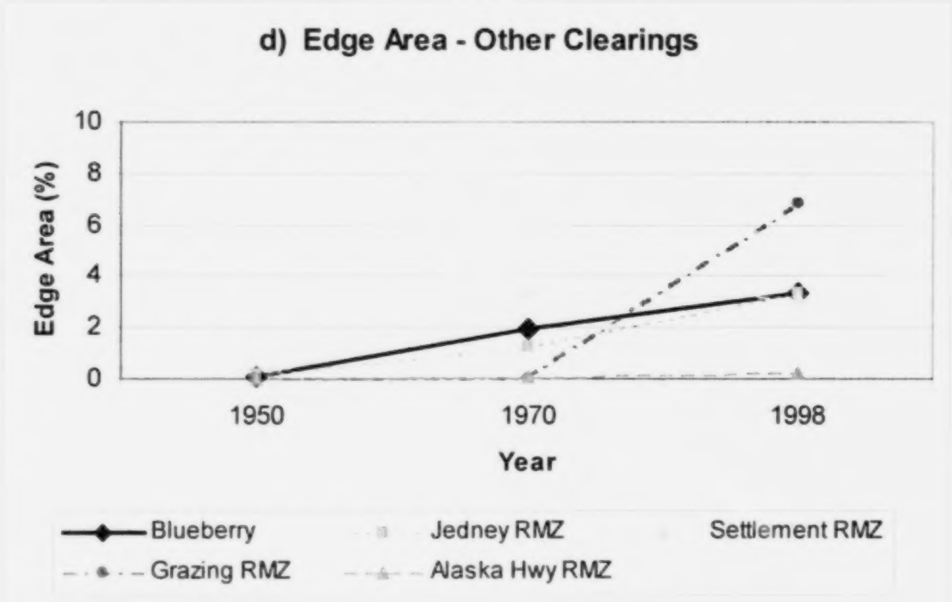
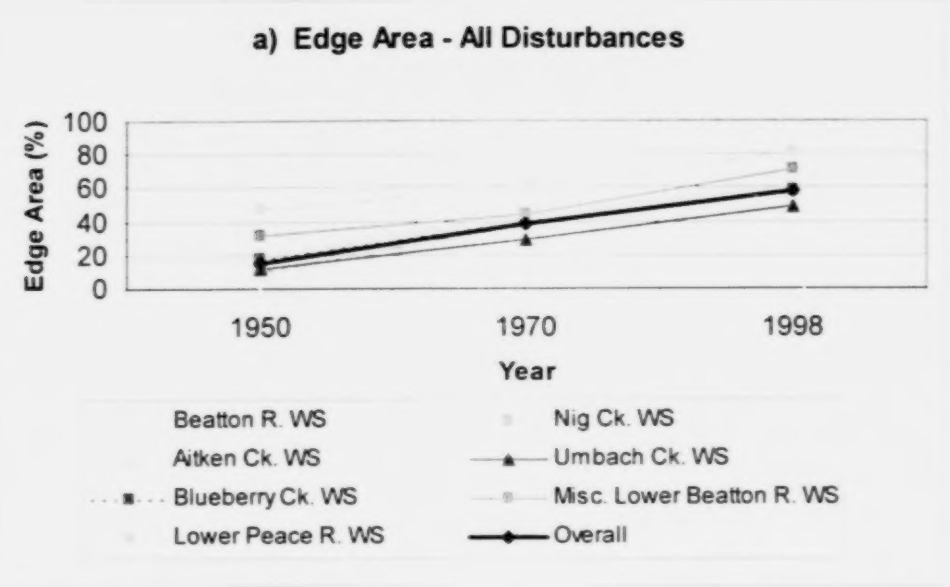
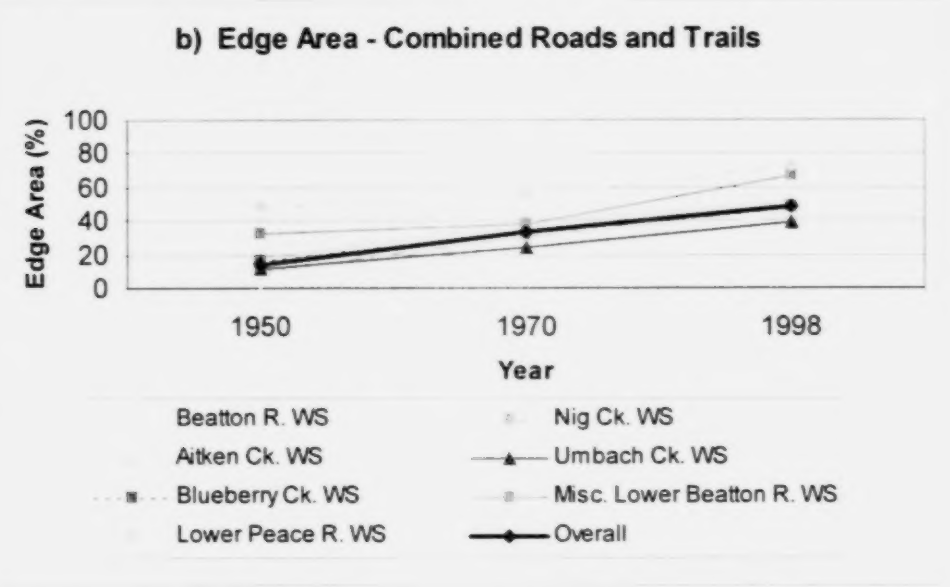


Figure 11. Trends in edge area in Blueberry study area RMZs (cont'd).

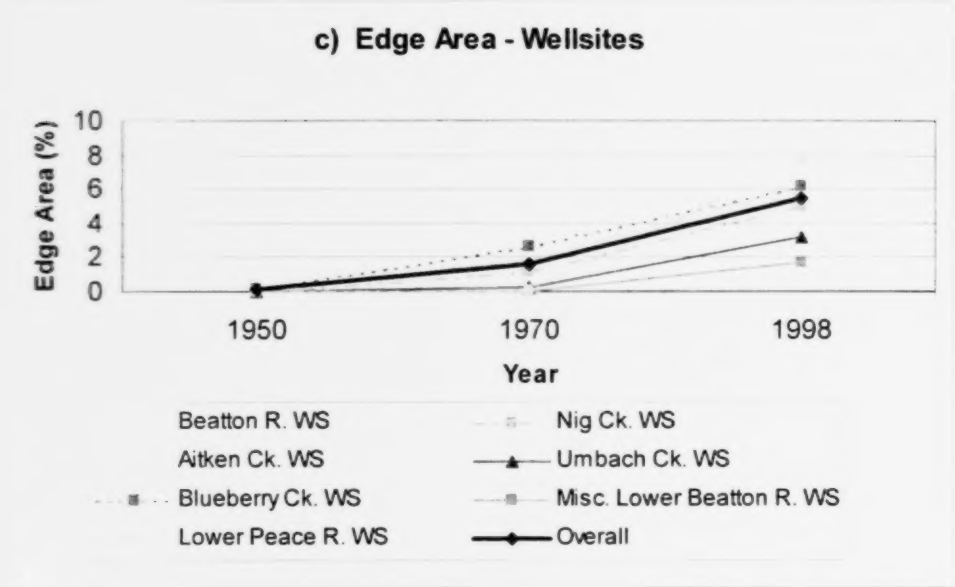


a) Edge Area - All Disturbances



b) Edge Area - Combined Roads and Trails

Figure 12. Trends in edge area in Blueberry study area subwatersheds.



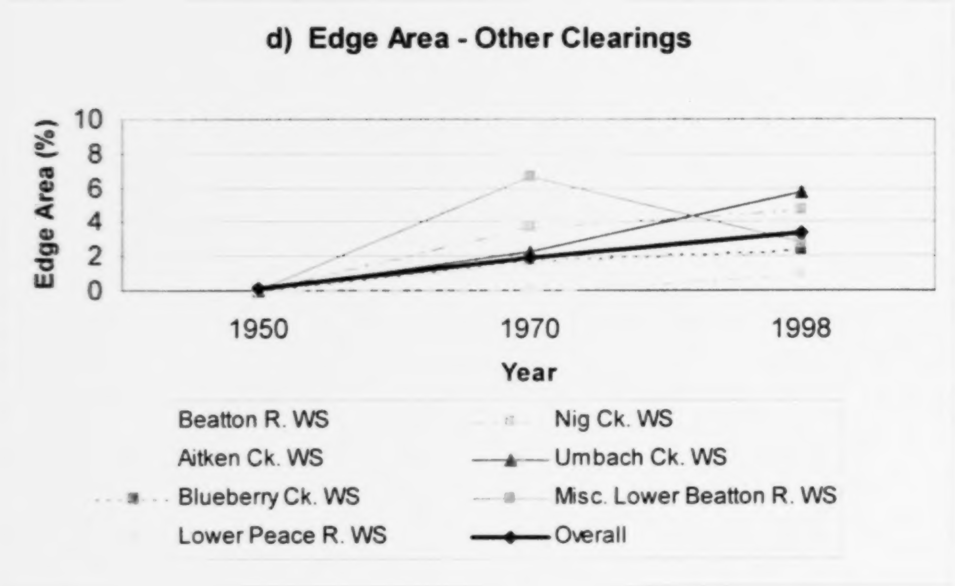


Figure 12. Trends in edge area in Blueberry study area subwatersheds (cont'd).

Total edge area currently represents about 58% of the overall Blueberry study area; most is associated with roads and trails. Edge area has increased gradually but consistently over the last 50 years. Edge area is highest in the Alaska Highway Corridor and Agriculture Settlement Area RMZs and the Lower Peace River and Lower Beatton River subwatersheds.

Theoretical models suggest that >40-50% edge area represents a threshold for ecological effects (Wilcove et al. 1986; Lee and Gosselink 1988; Laurance and Yensen 1991; With and Crist 1995). This threshold is currently exceeded throughout the Blueberry Case Study area, suggesting that habitat effectiveness has been compromised for sensitive interior species.

3.2.4.7 Core Area

Trends in the portion of the Blueberry study area considered to be relatively undisturbed are summarized by RMZ in Figure 13 and subwatershed in Figure 14.

Core areas greater than 500 m from possible high use human features are currently present on 15% of the overall Blueberry study area. The most rapid fragmentation of core areas occurred between 1950 and 1970. Ongoing fragmentation has reduced average core size from 630 to 115 ha since 1970. Based on median values, most core areas are currently less than 19 ha in size. Residual core area is highest in the Grazing Reserve 1 and Jedney RMZs and the Beatton River and Umbach Creek subwatersheds.

Core area sizes can be compared with minimum home range or patch size to assess their suitability for specific species. Black-throated green warbler, a representative interior forest songbird of concern found in the study area, appear to require a minimum of 40 ha of suitable habitat (Hannon 1992). Marten are a representative furbearer of concern that appear to require more than 100-200 ha of suitable habitat (Buskirk and Ruggiero 1994). Female grizzly bears appear to require a portion of their home range that is secure from high use human activities, and the concept of core security areas has been used for assessment and management of cumulative effects on this species. Core security areas are considered to be that portion of home range that corresponds to a 24 to 48 feeding bout of an adult female grizzly bear (Mattson 1993; Mace et al. 1996). Minimum areas of 450 ha to 1,010 ha have been used in assessments in western Canada and 60% of available habitat as core area has been identified as a management threshold for Banff National Park (Gibeau et al. 1996; CRC 1999; Kansas and Collister 1999; Gibeau 2000).

In 1950, core areas consisted of a few very large patches and several small patches. At this time, core area availability and core area size were likely not limiting warblers, marten, and grizzly bear, assuming suitable habitat existed. By the late 1990s, 38% of the remaining core areas were large enough to support warblers, 14 to 20% were large enough for marten, and only 3 to 6% were large enough for grizzly bears.

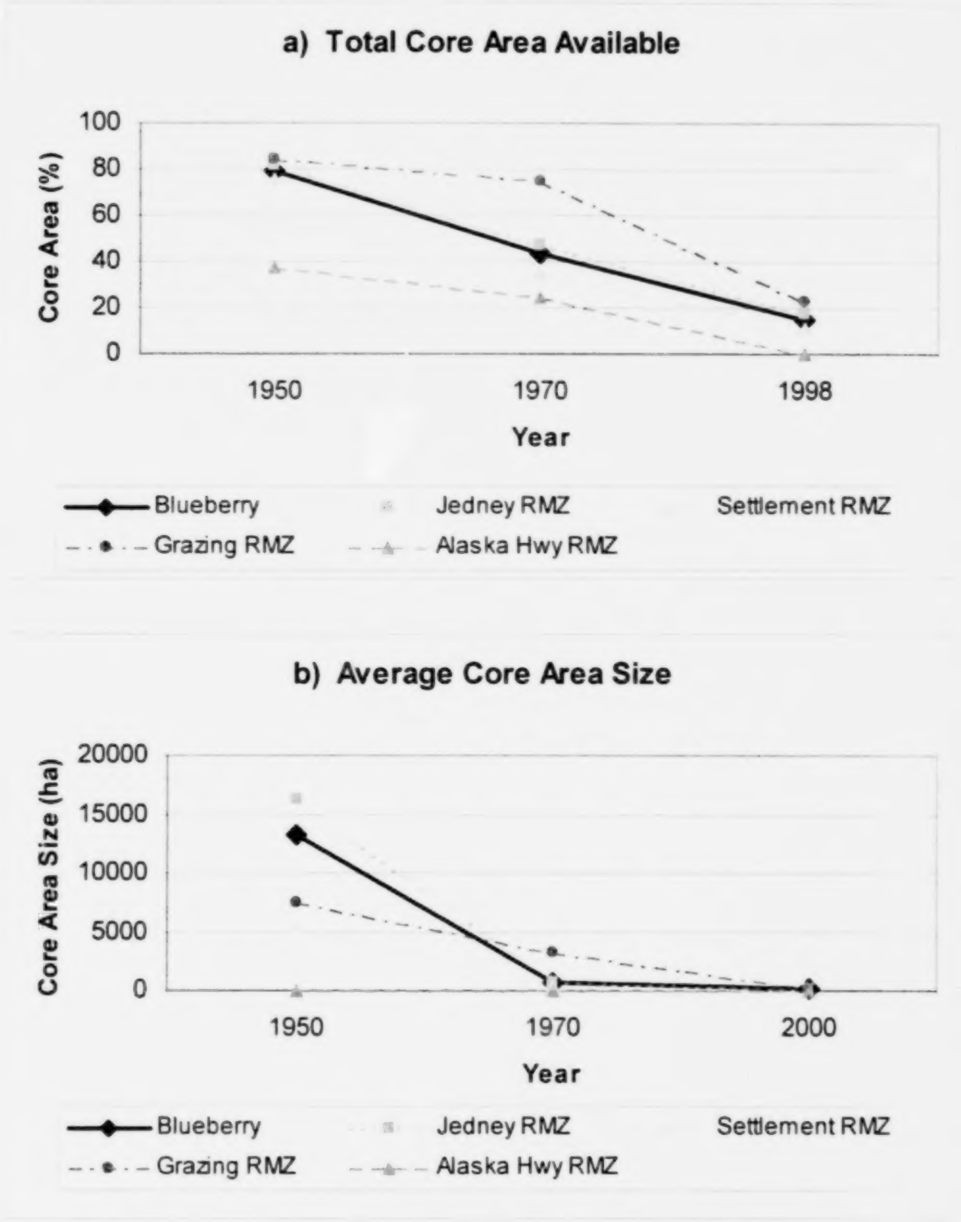
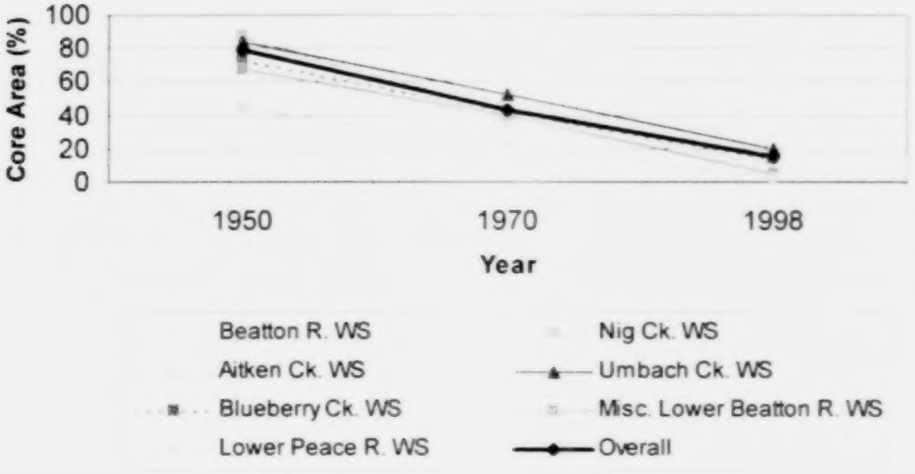


Figure 13. Trends in available core area in Blueberry study area RMZs.

a) Total Core Area Available



b) Average Core Area Size

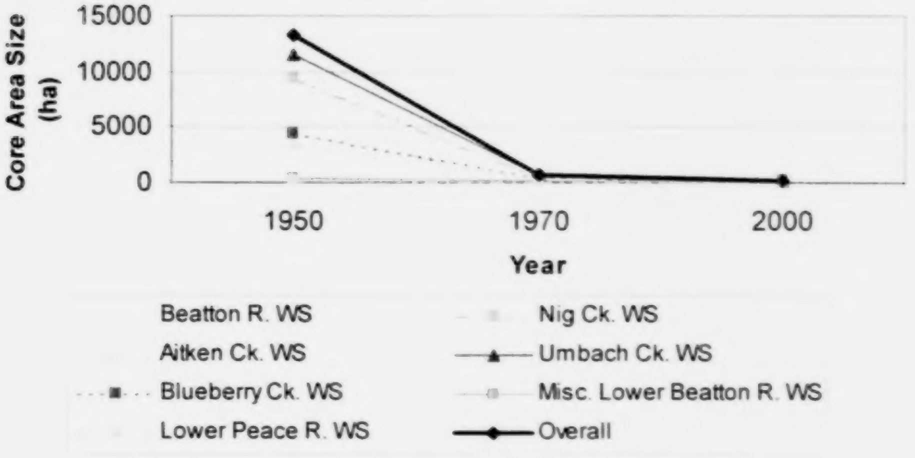


Figure 14. Trends in available core area in Blueberry study area subwatersheds.

3.2.4.8 Stream Crossing Index

Riparian features (clearings and roads) and stream crossings used for watershed analyses in the Blueberry study area are depicted in Figure 15. Trends in numbers of stream crossings in the Blueberry study area are summarized by RMZ in Figure 16 and subwatershed in Figure 17.

Streams in the Blueberry study area are currently crossed on average once every 7.7 km by primary and secondary roads, once every 2.7 km by truck trails, once every 20 km by utility corridors, and once every 0.8 km by cutlines. Total stream crossings are lowest in the Beatton River subwatershed (1.35 crossings/km), highest in the Lower Beatton River subwatershed (3 crossings/km), and intermediate (1.6 to 1.9 crossings/km) in remaining subwatersheds. Cutlines are the most common crossing feature (68 to 93% of combined crossings) in all watersheds except the Lower Peace River where primary and secondary roads comprise just over half of the stream crossings (Figures 15 and 16; Appendix A).

Expressed in terms of crossing frequency, stream crossings in the overall Blueberry study area were infrequent in 1950, with one linear corridor crossing every 4.2 km. By 1970, average stream crossing frequency had increased to one crossing every 1.2 km. At present, each stream in the study area is crossed by a linear corridor every 600 m.

Consistent increases in stream crossing frequency have occurred in the Blueberry study area since 1950; these have mirrored general development patterns. Road and trail crossings occur most frequently in the Alaska Highway and Agricultural Settlement RMZs.

Although there are no established threshold criteria for stream crossing frequency, stream crossing numbers in the Blueberry study area are lower than other areas of the eastern slopes in Alberta and British Columbia (Alliance 1997; Salmo 1999, 2000, unpub. data). Based on existing road and corridor patterns, Nig Creek is relatively accessible to fishermen and has moderate numbers of potential sediment sources and barriers to fish movements associated with corridor crossings. Other watercourses have more limited accessibility and low to moderate numbers of potential sediment sources.

3.2.4.9 Riparian Roads

Trends in the number of roads and trails constructed within 100 m of waterbodies in the Blueberry study area are summarized by RMZ and subwatershed in Figure 18. In the absence of site-specific watershed surveys of the Blueberry study area and data from other similar areas, hazard levels for valley roads were assigned from original IWAP rating scores (BCF and BCE 1995b).

Low:	0 to 0.12 km/km^2
Medium:	>0.12 to 0.25 km/km^2
High:	>0.25 km/km^2

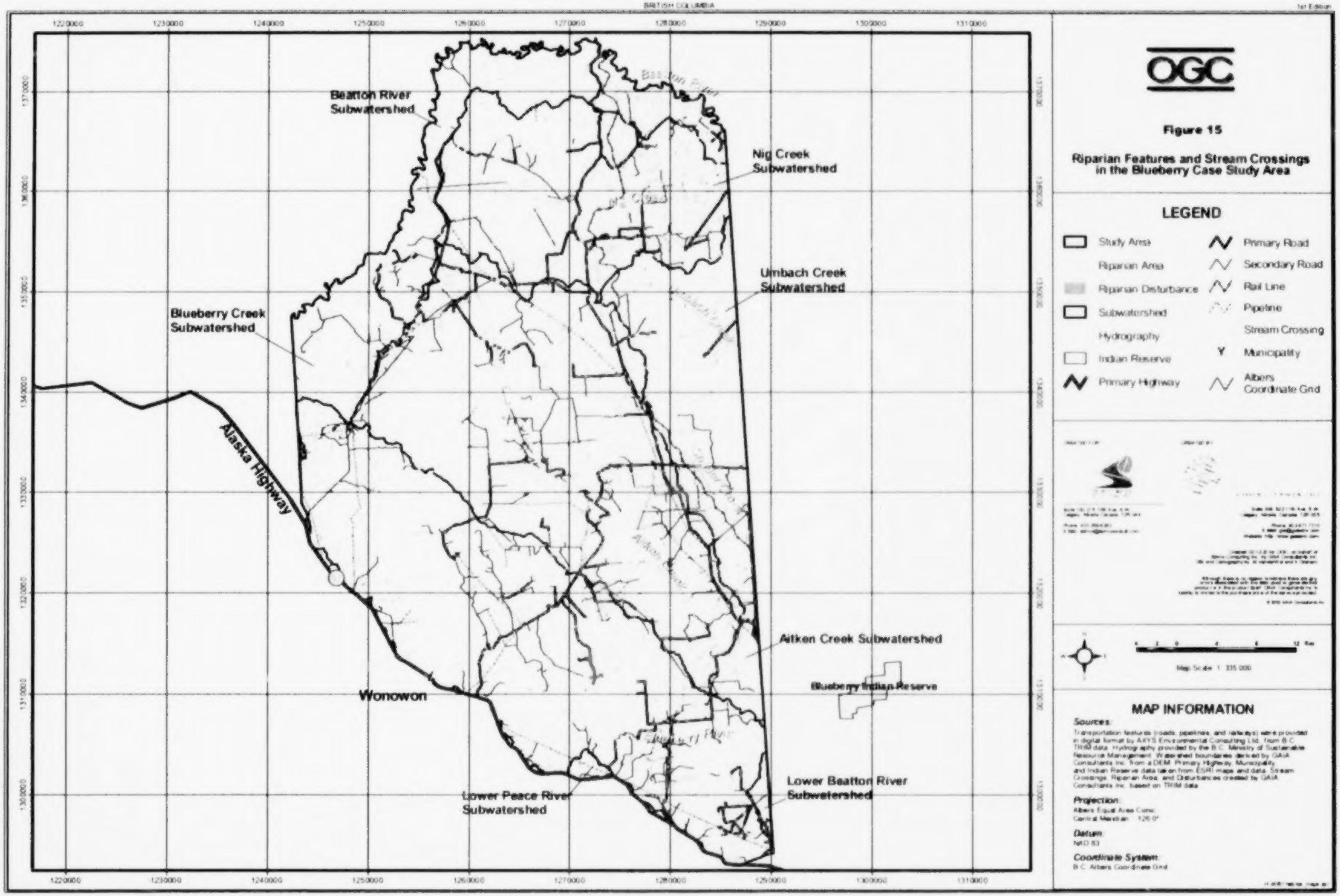


Figure 15

Riparian Features and Stream Crossings in the Blueberry Case Study Area

MAP INFORMATION

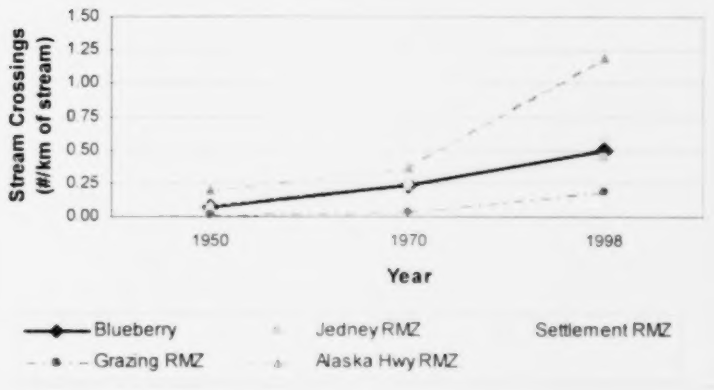
Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. Hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from a DEM. Primary Highway, Municipality, and Indian Reserve data taken from ESRI maps and data. Stream Crossings, Riparian Area, and Disturbances created by GAIA Consultants Inc. based on TRIM data.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

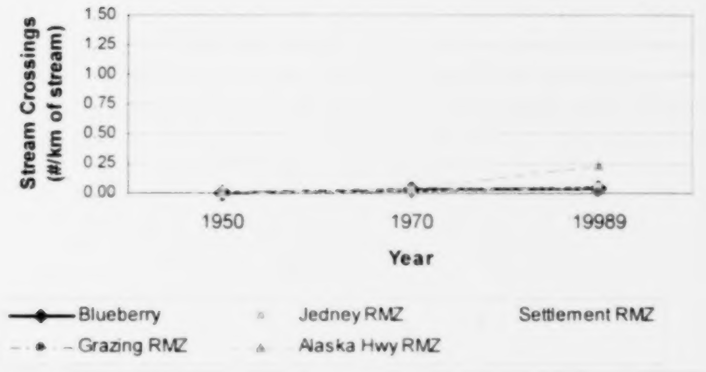
Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

a) Stream Crossings - Combined Roads and Trails



b) Stream Crossings - Pipelines



c) Stream Crossings - Cutlines

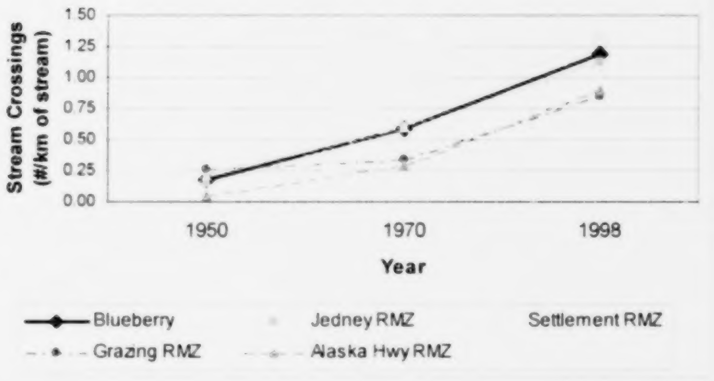
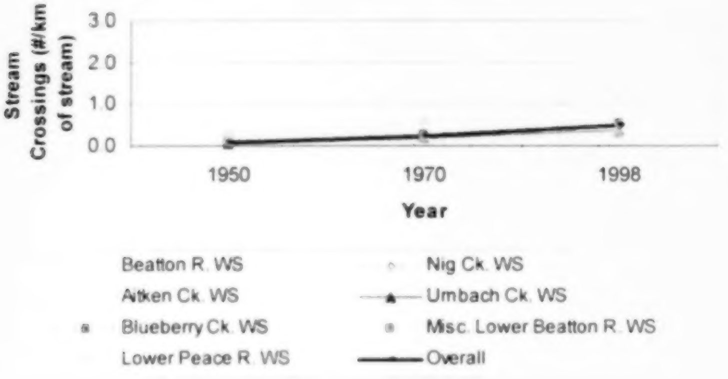
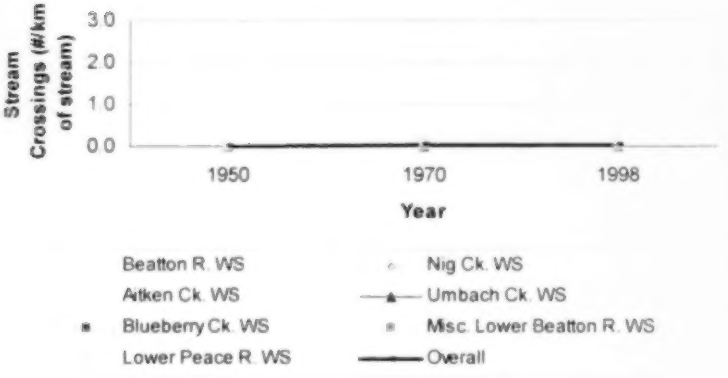


Figure 16. Stream crossing trends in Blueberry study area RMZs.

a) Stream Crossings - Combined Roads and Trails



b) Stream Crossings - Pipelines



c) Stream Crossings - Cutlines

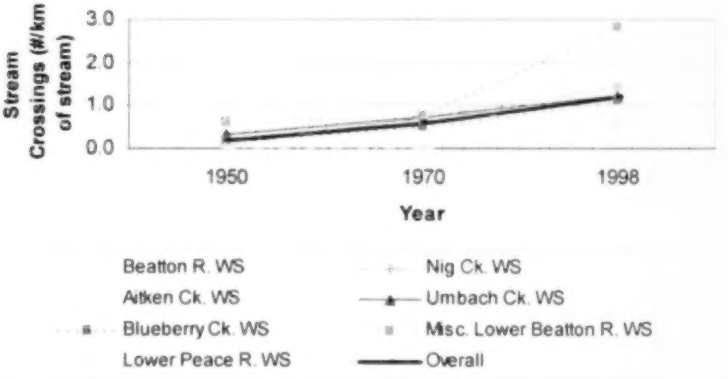
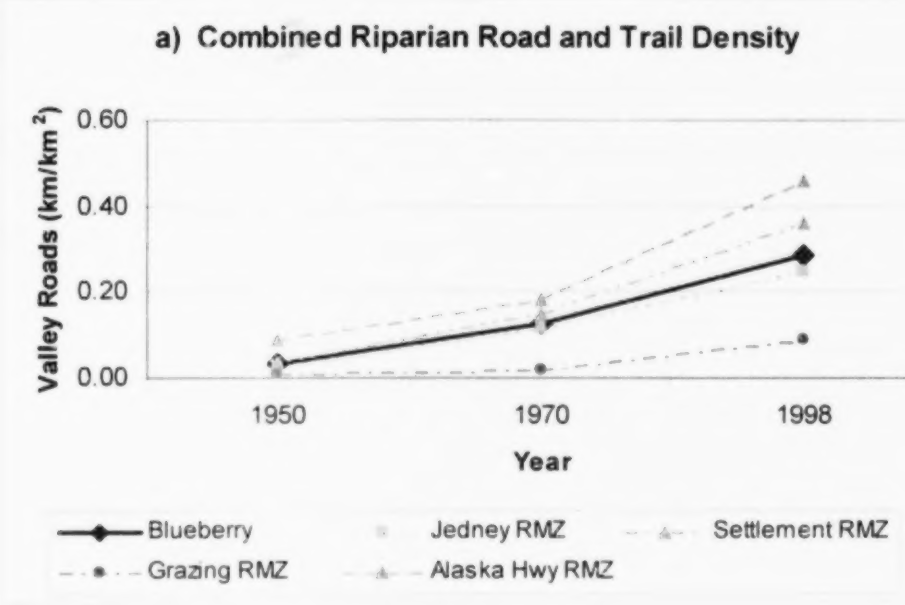


Figure 17. Stream crossing trends in Blueberry study area subwatersheds.



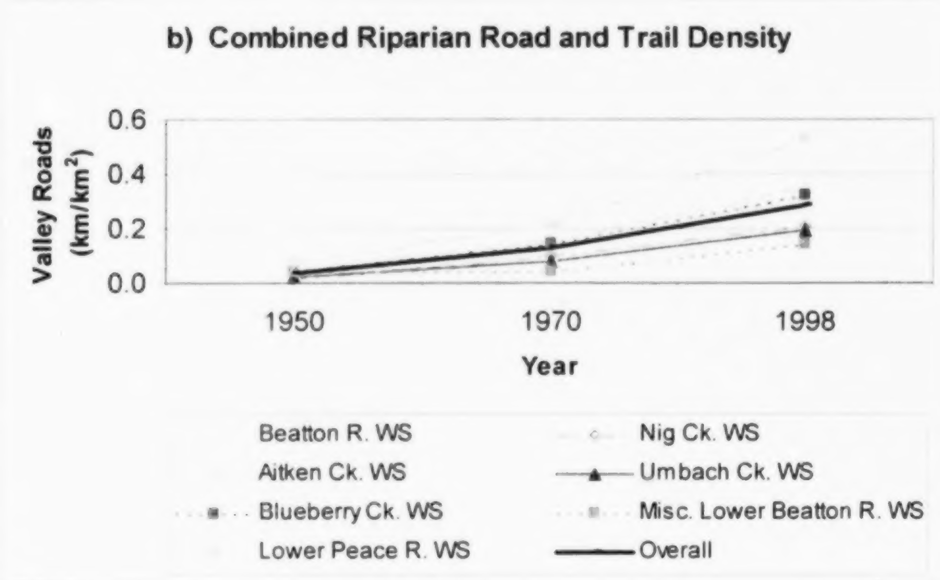


Figure 18. Riparian roads in Blueberry study area RMZs and subwatersheds.

In 1950, all subwatersheds in the Beatton River drainage had a Low aquatic hazard rating from valley roads and trails. By 1970, the aquatic hazard rating had increased to Medium in all Beatton River subwatersheds. The overall Blueberry study area currently has a High aquatic hazard due to valley roads and truck trails, as do the Aitken Creek and Blueberry River subwatersheds. All other subwatersheds in the Beatton River drainage have a Medium aquatic hazard.

3.2.4.10 Cleared Riparian Area

Trends in the amount of riparian area cleared in the Blueberry study area are summarized by RMZ in Figure 19 and subwatershed in Figure 20. In the absence of data site-specific watershed surveys of the Blueberry study area and data from other similar areas, hazard levels for riparian clearing were assigned from original IWAP rating scores (BCF and BCE 1995b):

Low: 0 to 9%

Medium: >9 to 18%

High: >18%

In the 1950s, riparian area cleared in the Blueberry Study Area overall, and all major subwatersheds represented a Low aquatic hazard based on the IWAP rating scores. The Aitken Creek and Miscellaneous Lower Beatton River subwatersheds contained the highest percentage (0.05% each) of riparian area cleared. Clearings accounted for nearly half the riparian clearing in the Aitken Creek watershed; cutlines almost a third. In the Miscellaneous Lower Beatton watershed, cutlines were the largest source of riparian clearing. The lowest levels of riparian clearing occurred in the Beatton River and Nig Creek subwatersheds (0.01% each).

The aquatic hazard in 1970 remained Low in all major watersheds and the overall Blueberry study area, which had 0.24% riparian area cleared, mostly attributable to cutblocks and clearings. The highest percentage of riparian clearing occurred in the Aitken Creek watershed (0.31%), followed closely by the Umbach Creek watershed (0.30%) and the Miscellaneous Lower Beatton River watershed (0.29%). Cutblocks and clearings accounted for the majority of the riparian area cleared (68 to 81%) of these watersheds. The lowest levels of riparian area cleared existed in the Beatton River watershed (0.08%) and the Lower Peace River watershed (0.11%).

As of 1998, the overall Blueberry study area, and each major watershed continue to support a Low aquatic hazard rating. The Miscellaneous Lower Beatton River watershed has the highest (0.80%) amount of cleared riparian area. Riparian clearing in the Umbach Creek watershed has increased to 0.62% followed by the Aitken and Blueberry creek watersheds with 0.58% riparian area cleared. Cutblocks and clearings continue account for the majority of the riparian clearing (67 – 77%) in each of these watersheds. The lowest levels of riparian clearing occur in the Nig Creek and Beatton River watershed (0.40 and 0.41%) respectively. Again, cutblocks and clearings are the largest source of riparian clearings in these watersheds.

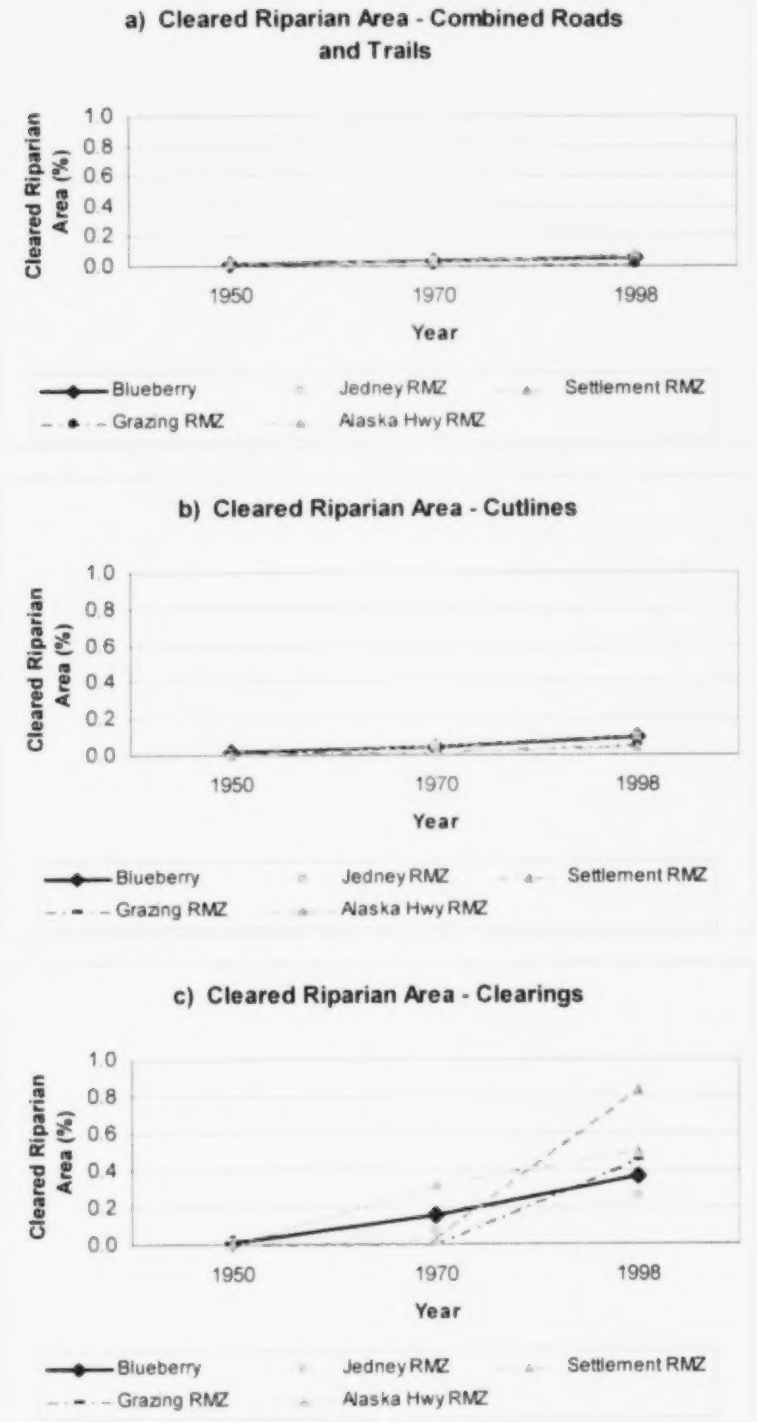
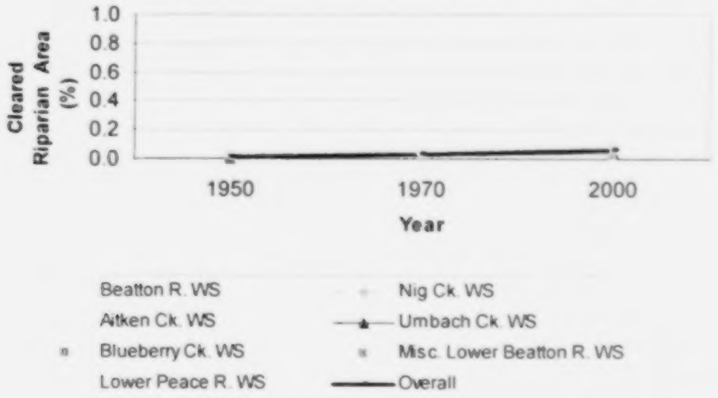
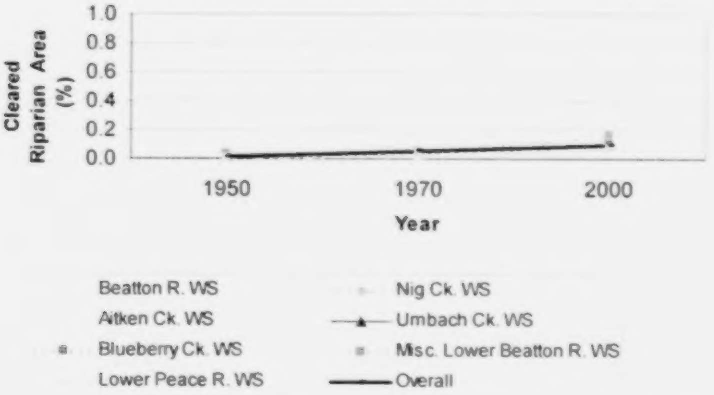


Figure 19. Trends in riparian clearing in Blueberry study area RMZs.


a) Cleared Riparian Area - Combined Roads and Trails


b) Cleared Riparian Area - Cutlines

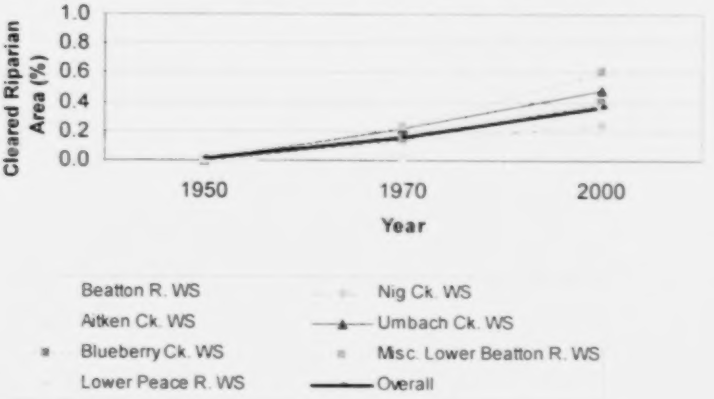

c) Cleared Riparian Area - Clearings

Figure 20. Trends in riparian clearing in Blueberry study area subwatersheds.

3.3 RENEWABLE RESOURCE TRENDS

Information on renewable resource availability, abundance and distribution were generated from a review of available files and interviews with representatives of MWLAP and MSRM in Fort St. John. Hunter and trapper harvest data were obtained to document historical trends in harvest and inferred abundance.

3.3.1 Natural Range of Variability

Naturally caused changes in fish and wildlife populations in the Blueberry Case Study area occur as a result of natural disturbances such as fire, disease, parasites, pests, floods, droughts, predation, and severe weather conditions. Fire and insects are the most important natural disturbances affecting the boreal forest. Floods, droughts, accelerated erosion, and channel barriers are the most important disturbances affecting aquatic habitat (Meehan 1991; Young 1994; Frissell and Bayles 1996; Andison 1999, 2000).

The natural disturbance regime is determined by long-term climate and short-term weather as well as physiographic and watershed characteristics. The frequency and magnitude of disturbance events affect the composition, productivity, and successional state of terrestrial and riparian vegetation as well as the connectedness and productivity of waterbodies (Ward 1989; Regier and Meisner 1990). This causes the distribution, pattern, and abundance (mosaic) of habitat to change in both time and space.

Fish and wildlife assemblages in northeast British Columbia have adapted to these natural disturbances, but individual species differ in their inherent ability to absorb disturbance and still persist as viable populations over time. At any point in time, species abundance and distribution reflects habitat availability and quality as well as biological factors such as immigration, emigration, and juvenile and adult mortality that are dictated by weather, predation rate, and life history patterns.

Observed variability in abundance appears to increase with the length of time over which it is monitored or calculated, and data sets of 50 years or more are required to accurately determine the natural range of variability (Pimm and Redfearn 1988; Thomas 1990).

Winter snow depth is a critical factor affecting wildlife populations in the Blueberry study area; Historical snow depth records for the Fort St. John airport are presented in Figure 21. Between 1971 and 2000, the long term average snow depth at this station was 31 cm, and extreme snow depth was 112 cm in 1974. Limiting snow depths are assumed to be 40 cm for deer, 50 cm for elk, and 65 cm for moose (Nietfeld et al. 1985). The 7 year period of mild winters beginning in 1984 provided very good conditions for ungulate population growth.

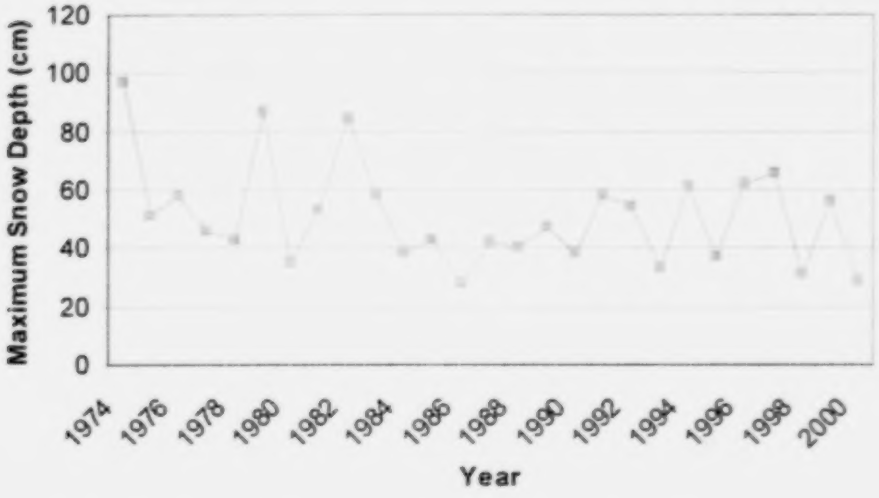


Figure 21. Maximum winter snow depth at Fort St. John airport.

3.3.2 Moose (*Alces alces*)

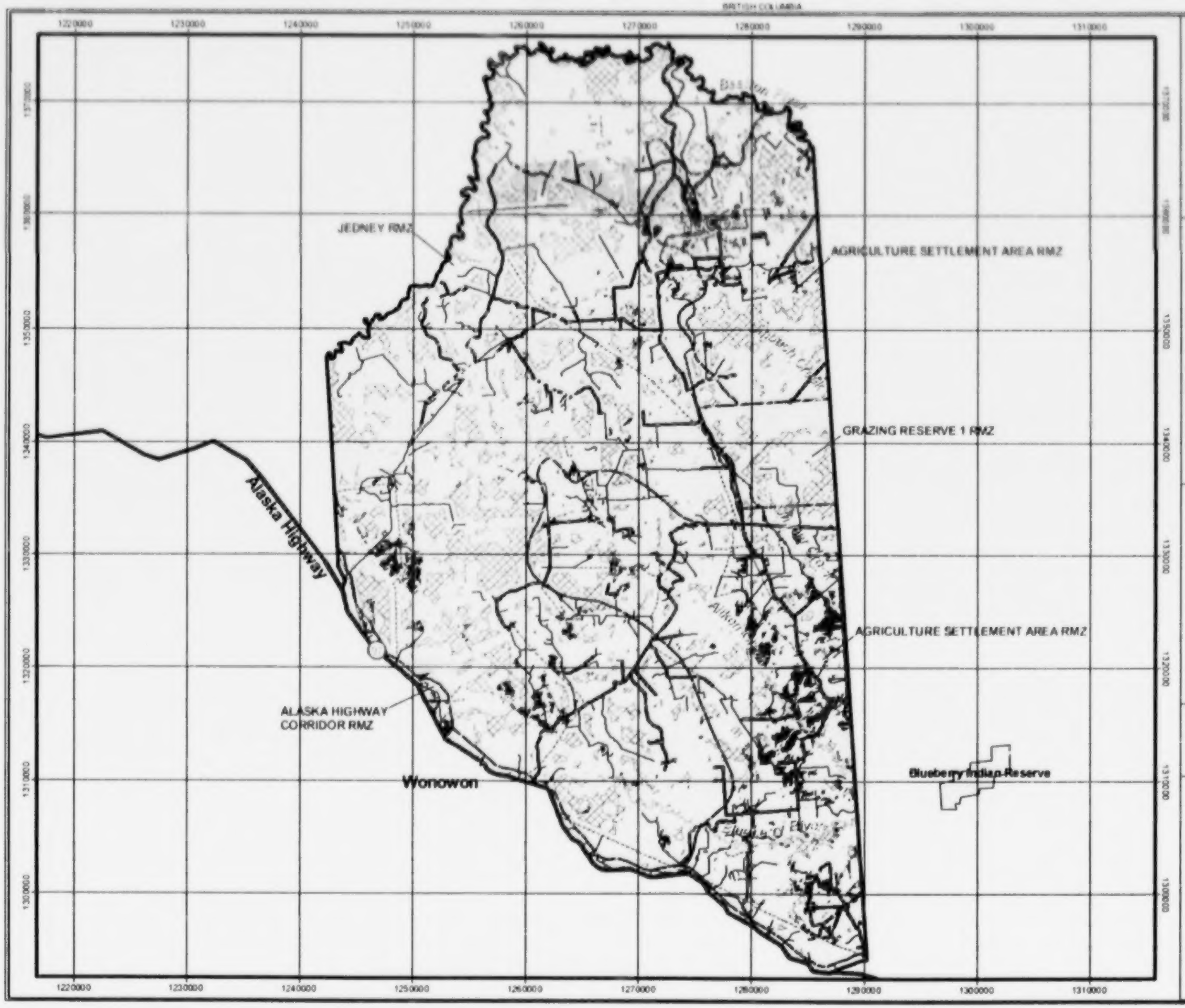
Moose are highly sought after by recreational and subsistence hunters and are the most abundant large mammal in the Blueberry Case Study area (Harper 1988). Moose are a habitat generalist with moderate reproductive potential and are relatively tolerant of human disturbance. Key factors limiting moose populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk),
- natural abiotic and biotic factors (predation, tick infestations and disease, snow depth, natural succession), and
- habitat loss and alteration (clearing, fire suppression).

3.3.2.1 Habitat Availability and Suitability

Current moose habitat suitability ratings derived for the Blueberry Case Study area are summarized in Table 7 and depicted in Figure 22.

Habitat in the Blueberry Case Study area was rated as High capability (Class 1) for moose by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use or seral stage.



OGC

Figure 22

Current Moose Habitat Suitability in the Blueberry Case Study Area

LEGEND

- Study Area
- RMZ Boundary
- Core Area
- Indian Reserve
- Primary Highway
- Primary Road
- Secondary Road
- Rail Line
- Pipeline
- Y Municipality
- Hydrography
- Albers Coordinate Grid

Moose Habitat Suitability Rating
- ☐ Nil
- Low
- Moderate
- ■ High
- No Data

Map Scale 1 : 335 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

Table 7. Current moose habitat suitability in the Blueberry Case Study area; (area classified as core in parentheses).

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Blueberry Overall	13,165 (1,193)	5 (<1)	158,933 (25,593)	60 (10)	82,680 (12,980)	31 (5)	8,260 (91)	3 (<1)
Agriculture Settlement RMZ	9,022 (690)	10 (<1)	59,564 (7,326)	64 (8)	21,720 (2,283)	23 (2)	2,818 (27)	3 (<1)
Alaska Highway RMZ	317 (0)	7 (0)	3,057 (11)	65 (<1)	757 (<1)	16 (<1)	542 (0)	12 (0)
Grazing Reserve RMZ	8 (0)	<1 (0)	6,108 (1,158)	67 (13)	2,581 (830)	28 (9)	375 (7)	4 (<1)
Jedney Enhanced Resource RMZ	3819 (504)	2 (<1)	90,204 (17,100)	58 (11)	57,623 9,866	37 (6)	4,525 (57)	3 (<1)

Approximately 65% of the Blueberry Case Study area is currently rated as Moderate to High Suitability habitat. Habitat suitability of burned, logged, or cleared areas between 5 and 20 years old is increased for 'edge' species such as moose, deer, and elk (Westworth and Telfer 1993; Puttock et al. 1996), and the availability of young seral stages affects moose density and distribution. During a 1998 aerial inventory in Management Unit (MU) 7-45, 26% of moose recorded were observed in cutblocks (MELP 1998).

Harper (1988) stated that observed moose density in MU 7-45 in the mid-1980's was well below the estimated carrying capacity of 8,730 animals, although biophysical ungulate capability mapping was not yet complete. Advancing seral stages of plant communities associated with fire suppression and intensive forest harvest was identified as the major factor limiting moose populations in the region. Balsam poplar riparian areas and shrub-grassland habitats were identified as particularly important habitats during deep snow winters (Harper 1988).

ALCES simulations indicate that average forest age has increased in the Blueberry Case Study area over the last 50 years – this has created a gradual decline in moose habitat effectiveness in this area. Prior to the introduction of efficient fire suppression in the late 1950's, a significant portion of moose habitat was likely rejuvenated by fire each year. Backmeyer et al. (1992) noted that headlines reflecting this were common in the local newspaper during the 1940's and 1950's.

Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of moose habitat in the Blueberry Case Study area (Figure 23). Each Monte Carlo simulation (shown in individual colour) was run over a 100 year period beginning in 1950. The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is typical of productive boreal forest. These simulations demonstrate that moose habitat in this area has a large natural range of variability due to fire.

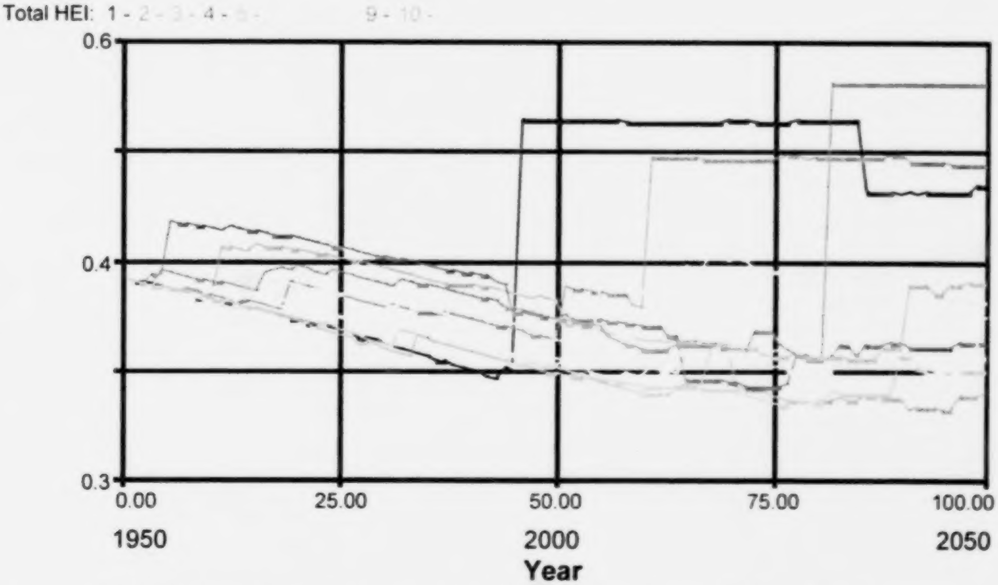


Figure 23. Predicted range of natural variability for moose habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

3.3.2.2 Population Trends

Harper (1988) estimated that 27,000 moose inhabited the Peace sub-region south of the Sikanni Chief River. Based on the knowledge of long-time regional wildlife staff, he also concluded that moose populations in the region had declined by roughly 50% between the early 1960's and early 1980's. Harper (1988) identified deteriorating habitat quality as the major contributing factor. He also concluded that the severe winter of 1981-1982, followed immediately by heavy tick infestations, had reduced some populations by 15%. Predation, agricultural conversion, and overharvest were also thought to have accelerated this decline in some areas.

Based on limited aerial inventory transect data collected in 1982, Harper estimated the moose population in MU 7-45 at 2,190 and declining slightly. A stratified random block inventory conducted in February 1998 resulted in a similar population estimate of 2,177 moose. Based on observed recruitment rates, the 1998 population was assessed as stable (MELP 1998).

Sport hunter harvest data provide an index of population abundance, although harvest patterns are affected by regulatory changes and weather, among other factors. Moose harvest in MU 7-45 has varied from a low of 88 animals to a high of 383 animals, but a gradual decline over the last 25 years is evident (Figure 24).

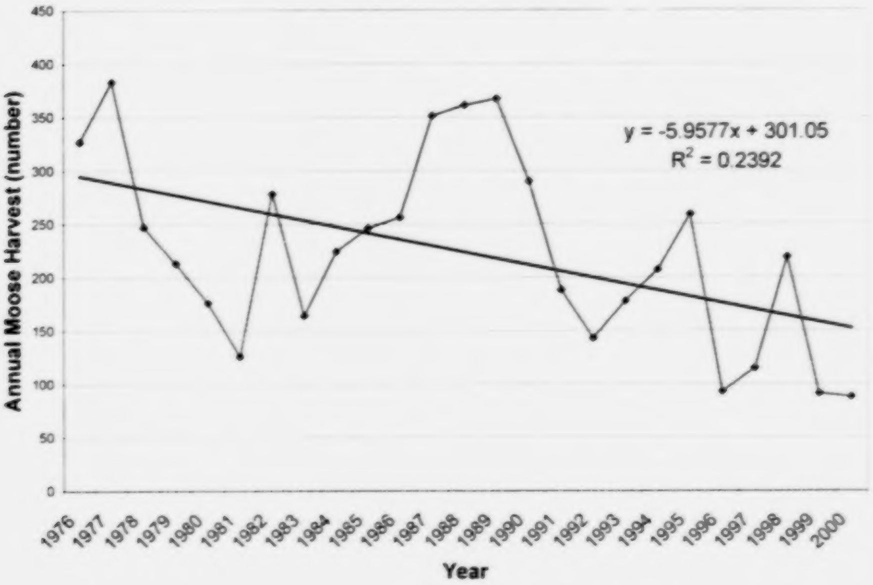


Figure 24. Annual moose harvest in Management Unit 7-45 (Blueberry Case Study area).

Annual harvest was dependent on hunter effort ($R^2 = 0.72$, $p < 0.01$), but harvest cycles can also be correlated with natural environmental factors. The population reduction in the early 1980's referenced by Harper (1988) is displayed in harvest data (although confounded by a one-year antlerless season in 1982). The increase displayed during the late 1980's corresponds to a 7 year period of mild winters beginning in 1984 that provided very good conditions for ungulate population growth (Figure 21). However, a dramatic increase in ATV use also occurred during this period that improved hunter success. Finally, harvest was similar during the two inventory years (1981 = 126; 1997 = 115), which suggests that it provides a reasonable index of relative moose abundance.

Inventory data indicate that the moose population in the Blueberry Case Study area has remained comparatively stable over the long-term. Hunter harvest data suggest that cyclical changes in relative abundance occurred between the two inventory surveys. The cumulative effect of human disturbance (access creation and clearing) on moose abundance is discussed further below.

3.3.2.3 Cumulative Effects Evaluation

Harper (1988) estimated that annual human-caused mortality of moose in MU 7-45 was 367 animals, approximately 17% of the population. Inferred sources of moose mortality were:

- 242: recreational hunter kill and estimated crippling loss,
- 50: suspected illegal kill (15% bulls, 60% cows, 25% calves),
- 50: estimated subsistence harvest, and
- 25: road and railway kill.

Because harvest was correlated with effort, moose hunter success (days per kill) statistics from MU 7-45 were used as a population index to relate changes in relative abundance to landscape habitat availability and land use. Although hunter effort has declined over the last 25 years, the average number of days required for a hunter to kill a moose has increased (Figure 25). This increase was not observed in the Sukunka Case Study area (Appendix 3).

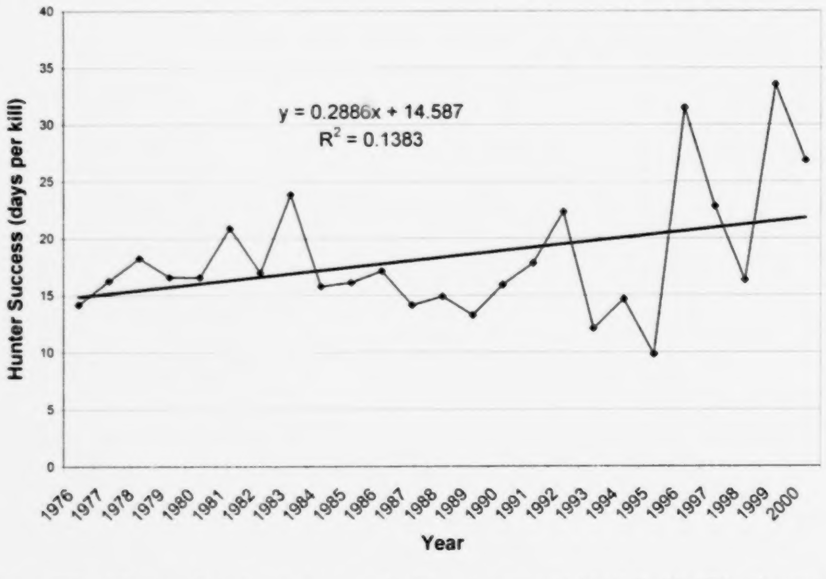


Figure 25. Moose hunter success in Management Unit 7-45 (Blueberry Case Study area).

The gradual decrease in hunter success could result from several factors: population decline, changes in harvest regulations, and changes in moose distribution or hunter access. As noted above, population decline does not appear to be an important factor. The influence of harvest regulations and landscape-scale patterns is discussed further.

Stepwise linear regression was used to evaluate the influence of habitat, land use, and environmental factors on harvest success. The state of habitat and land use indicators was interpolated using trend equations developed from 1950, 1970, and current (late 1990's) data. Regression statistics are summarized in Table 8.

Table 8. Factors affecting moose harvest success in the Blueberry Case Study area.

Independent Variables	R^2	P
Land Use Indicators		
Median Road and Trail Density (km/km^2)	0.17	0.04
Average Total Corridor Density (km/km^2)	0.15	0.05
Average Road and Trail Density (km/km^2)	0.15	0.05
Average Road Density (km/km^2)	0.15	0.05
Total Cleared Area (ha)	0.15	0.06
Average Trail Density (km/km^2)	0.13	0.08
Average Cutline Density (km/km^2)	0.13	0.09
Edge Area (ha)	0.09	0.15
Habitat Indicators		
Remaining Core Area (ha)	0.11	0.11
Remaining Moderate and High Suitability Core Area (ha)	0.10	0.11
Environmental Indicators		
Previous Years Maximum Snow Depth (cm)	0.01	0.66
Combined Indicators		
Median Road and Trail Density/Remaining Core Area	0.28	0.03
Median Road and Trail Density/Cleared Area	0.28	0.03
Median Road and Trail Density/Edge Area	0.28	0.03
Median Road and Trail Density/Remaining M/H Suitability Core	0.28	0.03

In the Blueberry area, median road and trail density provided a statistically significant prediction of harvest success; regression equations based on other linear corridor indicators were nearly significant. Land use indicators (total corridor density, road density, and trail density) individually provided better predictions than habitat indicators (cleared area, core area, edge area, high and moderate suitability core area). Core area, a generalized habitat indicator, provided slightly better predictive ability than an indicator incorporating habitat suitability (i.e., moderate and high suitability core area). Multiple linear regression equations incorporating complementary disturbance and habitat indicators (e.g., median roads plus trails and core area; cleared area and core area) were able to explain more of the variability in annual harvest success (Table 8).

Yearly moose harvest success was inversely related to the level of disturbance (Figure 26) and directly related to the availability of core areas (Figure 27). In other words, hunters were most successful at earlier stages of habitat fragmentation when more core area was available and disturbance (roads, trails, cutlines, and clearings) was lower.

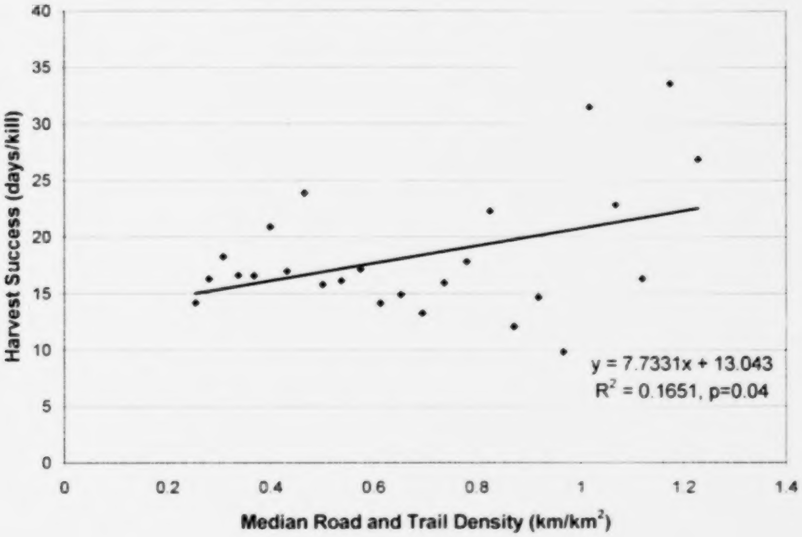


Figure 26. Relationship between moose harvest success and roads in the Blueberry Case Study area.

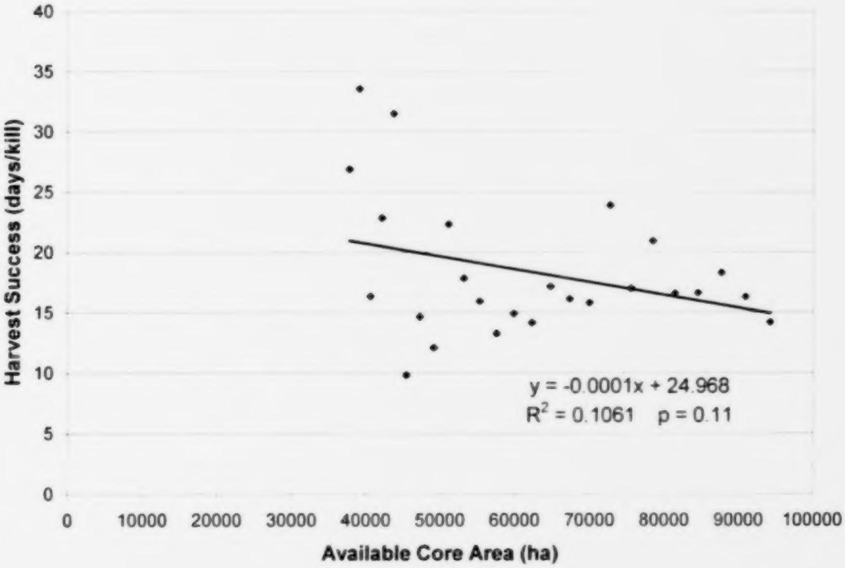


Figure 27. Relationship between moose harvest success and core area in the Blueberry Case Study area.

Core areas with High and Moderate suitability moose habitat have declined in the Blueberry Case Study area over the last fifty years and currently comprise only 10% of available habitat (Table 7). This indicates that most moose in this area now inhabit 'edge' areas where disturbance and direct human mortality risk is increased and habitat effectiveness may be reduced.

This increased cumulative effects risk has not been translated into population declines for moose in the Blueberry Case Study area. This is likely due to a combination of factors including restrictive harvest regulations, greater availability of early seral stages, and possibly reduced wolf and bear predation (e.g., Franzmann 1978, McNicol and Gilbert 1980; Payne et al. 1988; reviewed in Culling and Culling 2001). Harvest-related reductions in abundance of legal animals are known to occur near disturbance features such as roads and cutblocks (e.g., Rempel et al. 1997), but these may not result in population changes at the regional scale (Schneider and Wasel 2000). Moose harvest regulations in the Blueberry Case Study area have become increasingly stringent since the late 1970's and legal harvest is currently limited to a small number of males that meet stringent antler size restrictions.

ALCES simulations indicate that moose habitat effectiveness declined by roughly 10% between 1950 and 2000. This is attributed to natural succession of early seral stages and direct loss of habitat by ongoing forest harvest, access construction, and agricultural conversion. A continued, gradual decline is projected over the next 50 years. Both historical and projected future decline in moose habitat effectiveness are within the range of natural variability (Figure 23).

In summary, ongoing clearing and access development have reduced moose habitat effectiveness in this area and dramatically reduced the availability of relatively undisturbed core areas. Land use and habitat indicators, particularly median road and trail density, provided reliable predictions of hunter success, an index of mortality risk and population abundance. However, increased human mortality risk has not resulted in detectable population declines; this is likely due to application of restrictive harvest regulations that have offset increased access and moose vulnerability.

3.3.3 Caribou (*Rangifer tarandus*)

Woodland caribou have low ecological resilience; they are a habitat specialist, intolerant of human disturbance, and have low reproductive productivity (Bergerud 1974). Two woodland caribou ecotypes are present in northeast British Columbia, 'northern' and 'boreal' (Heard and Vagt 1998). Most individuals of the 'northern-ecotype' spend the spring, summer and fall in subalpine spruce/balsam and lodgepole pine forests and alpine tundra. During winter, they use a combination of windswept alpine and low- to high-elevation mature to old coniferous forests where lichens are most abundant and available. Deciduous and mixedwood forests appear to be avoided. Considerable individual and between-year variability in habitat use is observed. Some individuals remain in low elevation coniferous BWBS forests year-round (Edmonds and Bloomfield 1984; Sopuck 1985; Murray 1992; Backmeyer 1994; Brown and Hobson 1998; Apps et al. 2001, Culling and Culling 2001).

'Boreal-ecotype' caribou reside in low elevation coniferous forests year-round. Treed fens and bogs and black spruce forest appear to be preferred habitat. Distributions of the two caribou ecotypes may overlap during winter (Bradshaw et al. 1995; Stuart-Smith et al. 1997; Brown and Hobson 1998; Anderson et al. 1999, Rettie and Messier 2000).

Woodland caribou within the Jedney RMZ and Blueberry Case Study area are assumed to be widespread at low densities. They may represent both migratory and resident subpopulations as well as both northern- and boreal-ecotypes. Key factors limiting woodland caribou populations are:

- natural abiotic and biotic factors (wolf and bear predation, disease, snow, fire),
- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk), and
- habitat loss and alteration (clearing and alteration of seral stage distribution).

3.3.3.1 Habitat Availability and Suitability

Habitat in the Blueberry area was rated as Very Low capability (Class 5) for caribou by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use or seral stage. Current caribou habitat suitability ratings derived for the Blueberry Case Study are summarized in Table 9 and depicted in Figure 28.

Table 9. Current caribou habitat suitability in the Blueberry Case Study area (area classified as core in parentheses).

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Blueberry Overall	288 (12)	<1 (<1)	12,713 (2,187)	5 (<1)	174,904 (30,005)	67 (11)	75,133 (7,653)	29 (3)
Agriculture Settlement RMZ	0 (0)	0 (0)	3,099 (571)	3 (<1)	51,431 (6,181)	55 (7)	38,593 (3,573)	41 (4)
Alaska Highway RMZ	0 (0)	0 (0)	156 (<1)	3 (<1)	3,505 (5)	75 (<1)	1,011 (7)	22 (<1)
Grazing Reserve RMZ	0 (0)	0 (0)	1,191 (402)	13 (4)	6,130 (1,359)	68 (15)	1,750 (232)	19 (3)
Jedney Enhanced Resource RMZ	288 (12)	<1 (<1)	8,267 (1,214)	5 (<1)	113,838 (22,460)	73 (14)	33,779 (3,841)	22 (2)

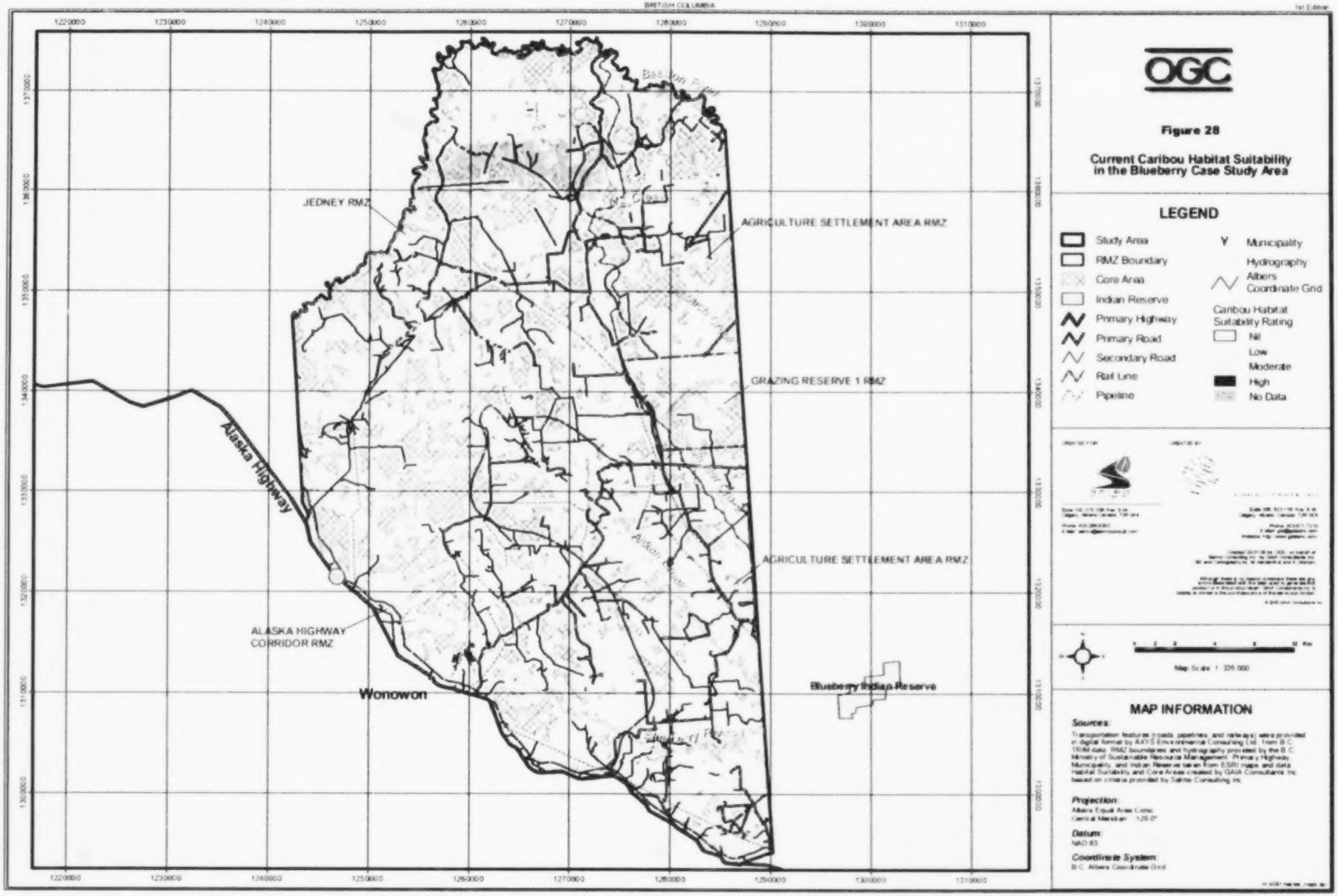


Figure 28

Current Caribou Habitat Suitability in the Blueberry Case Study Area

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:

Albers Equal Area Conic

Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

The Blueberry Case Study area has Low overall suitability for woodland caribou and almost 30% of the area has Nil suitability. Most Moderate and High Suitability habitat is located in the Jedney RMZ. Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of woodland caribou habitat in the Blueberry Case Study area (Figure 29). Each Monte Carlo simulation was run over a 100 year period beginning in 1950.

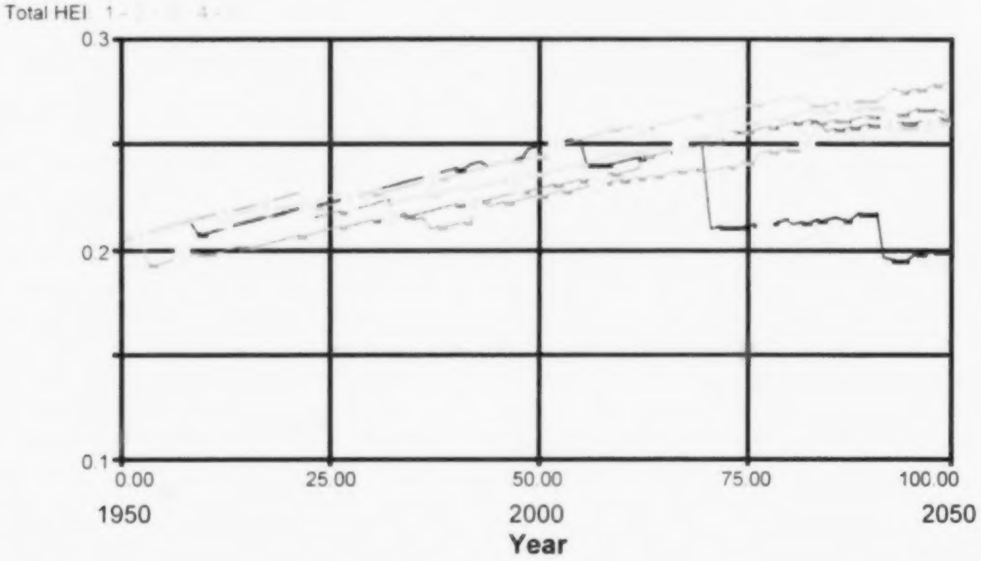


Figure 29. Predicted range of natural variability for caribou habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is somewhat low relative to occupied caribou range in the boreal forest. These simulations demonstrate that in the absence of human disturbance, woodland caribou habitat in the Blueberry Case Study area is gradually improving as forest age increases and that natural variability due to fire is low in this area.

3.3.3.2 Population Trends

Harper (1988) crudely estimated the caribou population in the Peace sub-region (south of the Sikanni Chief and Cyprus rivers) to be about 1,100 and likely increasing, based on reconnaissance aerial survey data. More recent estimates within the Peace sub-region have placed the population at approximately 800 animals. Harper (1988) listed caribou occurrence within MU 7-45 as 'occasional' and provided no population estimate.

During a stratified random block moose inventory in MU 7-45 during February 1998 (MELP 1998), 63 caribou were observed in sampled blocks comprising 21.7% of the total MU. Simple extrapolation with no allowance for sightability (or the fact that the inventory was stratified for moose density) provides a mean density of 47 caribou/100 km^2 or 290 caribou for the MU. This density is high compared to other reported densities in the region (e.g., Penner 1981; Bergerud and Elliot 1998; Stevenson et al. 2001).

Limited anecdotal evidence indicates that woodland caribou populations are significantly lower than historical levels. Harper (1988) suggested that a major population crash had occurred in the sub-region in the early 1970's. Bergerud et al. (1984) note that the Pink Mountain-Prophet River caribou herd declined from at least 3,500 animals in 1969 to possibly only 300-400 animals in 1978. These conclusions are supported by regional hunter harvest data. One aboriginal resident of the area can recall, as a child, witnessing large caribou movements over the course of several days in the Beatton River area (B. Webster, WLAP, pers. comm.). Harper (1988) suggested possible causes of the decline include deep snow winters in the late 1960's and early 1970's, and increased wolf predation.

Excessive harvest is recognized as a possible threat to caribou populations and likely contributed to the major declines of the 1970's when liberal cow and bull seasons existed throughout the Peace sub-region. Bergerud et al. (1984) attributed the decline in the Pink Mountain-Prophet River herd to overharvest. This occurred because the Alaska Highway provided hunter access to caribou that came unusually far east, and because hunters used snow machines and cutlines to reach animals. Legal cow harvest was terminated in 1976 and bull seasons were significantly reduced in area and duration. An antler restriction was placed on bulls in 1986 to further reduce the legal harvest.

Dramatic declines also occurred in woodland caribou populations in southern British Columbia (Harding and McCullum 1994), and western Alberta (Bloomfield 1979; Stelfox and Stelfox 1993; Dzus 2001) between 1950 and 1980. In all areas, this decline occurred concurrently with an increase in road access and logging that is believed to have significantly increased mortality from hunters and wolves (Bergerud et al. 1984; Seip 1992; Harding and McCullum 1994). This is considered to be a good example of the cumulative effects of human development and habitat fragmentation (Harding and McCullum 1994).

Annual direct caribou mortality in the Blueberry area is currently assumed to be very low, although the extent of subsistence and illegal harvest are unknown. There has been no legal hunting season for caribou in MU 7-45 since 1975. While vehicle mortality of woodland caribou is an issue in some areas (e.g., along the Alaska Highway in the vicinity of the Prophet River), it is very low in other areas such as the Sukunka Case Study area (Antoniuk 1994).

3.3.3.3 Cumulative Effects Evaluation

Established cumulative effects indicators and thresholds for caribou were reviewed in Section 6.1.3 of Appendix 1.

Relatively undisturbed core areas with High and Moderate suitability woodland caribou habitat have declined in the Blueberry Case Study area over the last fifty years and currently comprise less than 1% of available habitat (Table 9); generalized core areas currently represent 15% of the study area. This is well below the 50% to 60% caribou persistence threshold (Section 6.1.3 in Appendix 1), and High and Moderate suitability core area is well below this threshold. Total access corridor density in this area also exceeds the 3 km/km^2 woodland caribou persistence threshold (Section 6.1.3 in Appendix 1).

An ALCES simulation was also conducted to evaluate the effects of human development on caribou habitat effectiveness in the Blueberry Case Study area. The simulation was begun in 1950 and uses development trends calculated for this area; habitat effectiveness was assumed to be lost near disturbance features due to edge effects (see Section 2.3.1 and Appendix 1). These simulations indicate that the Blueberry area provided no effective habitat for woodland caribou by 1980 (Figure 30) due to indirect effects of clearing, land conversion, and access corridor construction. This loss is well below the range of natural variability (Figure 29).

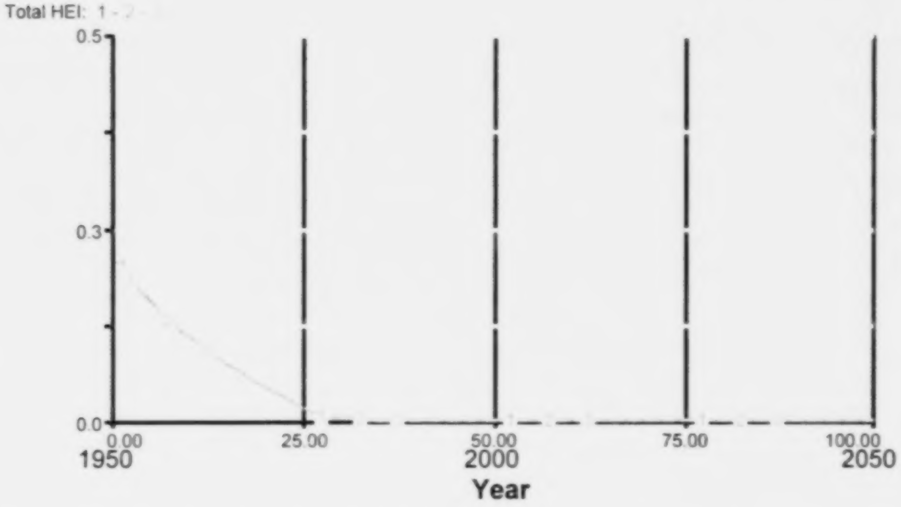


Figure 30. Predicted caribou habitat effectiveness in the Blueberry Case Study area with human development (Habitat Effectiveness Index on y axis).

Cumulative effects evaluations using several independent land use and habitat-based methods consistently conclude that woodland caribou are unlikely to persist in the Blueberry Case Study area. This is consistent with observations that this area received only occasional woodland caribou use by the early 1980's (Harper 1988). The status of woodland caribou in the Jedney RMZ northwest of the Blueberry Case Study area warrants further study.

3.3.4 Elk (*Cervus elaphus*)

Elk are highly sought after by recreational hunters and are increasing in abundance in northeast British Columbia. Elk are a habitat generalist with moderate reproductive potential. They are generally intolerant of human disturbance, but habituate to predictable, non-threatening activities. Key factors limiting elk populations are:

- natural abiotic and biotic factors (predation, snow depth, disease, fire),
- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk), and
- habitat loss and alteration (clearing, fire suppression, reduced habitat effectiveness near human activity).

3.3.4.1 Habitat Availability and Suitability

Habitat in the Blueberry Case Study area was rated as Moderately High capability (Class 2) for elk by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use.

Current elk habitat suitability ratings derived for the Blueberry Case Study are summarized in Table 10 and depicted in Figure 31.

Table 10. Current elk habitat suitability in the Blueberry study area (area classified as core in parentheses).

Analysis Unit	**Suitability Class**							
	High		**Moderate**		**Low**		**Nil**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Blueberry Overall	3,368 (128)	1 (<1)	89,694 (11,013)	34 (4)	161,116 (28,438)	61 (11)	8,859 (278)	3 (<1)
Agriculture Settlement RMZ	2,683 (89)	3 (<1)	41,873 (4,149)	45 (4)	45,647 (6,050)	49 (6)	2,921 (37)	3 (<1)
Alaska Highway RMZ	123 (0)	3 (0)	2,473 (4)	53 (<1)	1,535 (8)	33 (<1)	542 (0)	12 (0)
Grazing Reserve RMZ	<1 (0)	0 (0)	3,507 (489)	39 (5)	5,149 (1,483)	57 (16)	415 (20)	5 (<1)
Jedney Enhanced Resource RMZ	562 (38)	<1 (<1)	41,841 (6,372)	27 (4)	108,785 (20,896)	70 (13)	4,987 (221)	3 (<1)

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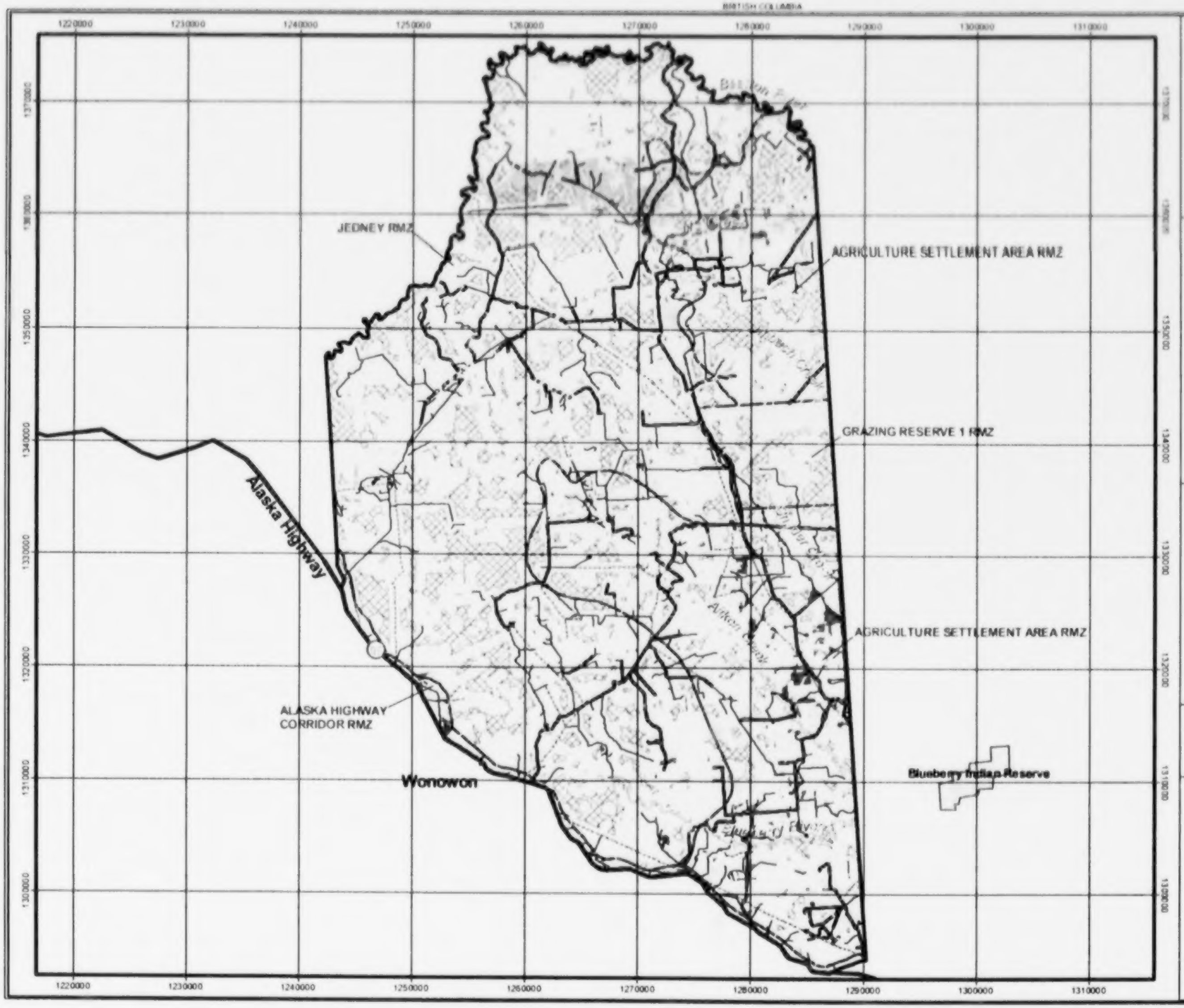

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Figure 31

Current Elk Habitat Suitability in the Blueberry Case Study Area

LEGEND

- ▭ Study Area
- ▭ RMZ Boundary
- ▨ Core Area
- ▭ Indian Reserve
- Primary Highway
- Primary Road
- Secondary Road
- Rail Line
- Pipeline
- Y Municipality
- Hydrography
- Albers Coordinate Grid

Elk Habitat Suitability Rating
- ☐ Nil
- Low
- Moderate
- ■ High
- No Data

Map Scale 1 : 335 000

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

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NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

Approximately 35% of the Blueberry Case Study area is currently rated as Moderate to High Suitability elk habitat; most is located in the southeast third of the study area where mixedwood forests are more common (Figure 3). Habitat suitability of burned, logged, or cleared areas between 5 and 20 years old is increased for 'edge' species such as elk, moose, and deer (Westworth and Telfer 1993; Puttock et al. 1996); the availability of young seral stages (forage) and steep southwest aspect shrub/grass communities (overwintering) affects elk density and distribution. Suitable overwintering habitat is extremely limited east of the Alaska Highway and north of the Blueberry River and elk are uncommon in MU 7-45 and the Blueberry Case Study area.

3.3.4.2 Population Trends

Elk are believed to have been historically common along the Peace River and its tributaries but disappeared along with wood bison in the mid-1800's. Elk populations in the Peace Lowland ecosection have undergone dramatic expansion in the past two decades. The source for much of this expansion was a small herd on the lower Moberly River, which was first noted during an aerial survey in 1966. By 1988 the population in the Peace sub-region was estimated at 890 (Harper 1988). Elk herds now occur throughout the sub-region where sufficient critical wintering habitat exists. Few elk were noted in the Blueberry area in the mid-1980's, but the regional population was reported to be increasing rapidly (16% per year; Harper 1988).

Sport hunter harvest data provide an index of population abundance, although harvest patterns are affected by regulatory changes and weather, among other factors. Prior to 1985, elk hunting in the Peace sub-region south of the Sikanni Chief River was confined to two MUs in the Murray and Wapiti river drainages. By 1990, general bull seasons were established in virtually all MUs where elk were known to exist, including MU 7-45. Harvest levels in this MU have been low (0 to 4 animals), but a gradual increase is evident over the last 25 years (Figure 32), suggesting that elk relative abundance has increased. Elk kills reported in 1978 and 1981 may be anomalous, as there was no legal elk season in MU 7-45 at that time.

3.3.4.3 Cumulative Effects Evaluation

Models relating elk habitat effectiveness to road and trail density have been developed for hunted elk populations in Oregon (e.g., Thomas et al. 1979, 1988; Lyon 1983, 1984). These models suggest that current road and trail density in the Sukunka Case Study area has reduced elk habitat effectiveness by 45% to 60%. This is consistent with calculations that less than 5% of the Blueberry Case Study area provides Moderate and High suitability habitat within relatively undisturbed core areas. Recent work to validate a commonly used elk-road model confirmed that elk avoided roads during spring and summer, but found that the model overestimates the relative loss of habitat effectiveness (Rowland et al. 2000).

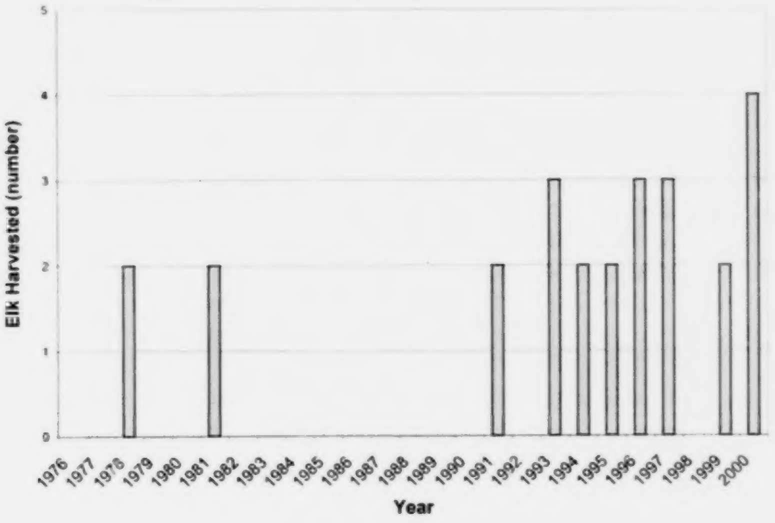

Figure 32. Annual elk harvest in Management Unit 7-45 (Blueberry Case Study area).

Insufficient data were available to directly examine the effect of combined human activities on elk abundance in the Blueberry Case Study area. Ongoing clearing and access development have reduced elk habitat effectiveness, but the lack of suitable wintering habitat appears to be primary factor limiting elk in this area.

3.3.5 Grizzly Bear (*Ursus arctos*)

The grizzly bear is widely used as an umbrella species for the assessment and management of cumulative effects at regional scales (e.g., Noss et al. 1996; Kansas 2002). Grizzly bear are Blue-listed in British Columbia, classed as Special Concern by COSEWIC (2002), and are classified as an Identified Wildlife Species (BCF and MELP 1999a). Estimated grizzly bear numbers are below historic and current potential in northeast British Columbia and have been extirpated from the Peace River lowlands. Local populations elsewhere in the region are not considered to be at risk (Cannings et al. 1999; Culling and Culling 2001).

Grizzly bears are considered to have low ecological resilience (Weaver et al. 1996). Reproductive rate is the lowest recorded among North American land mammals. Subadult female dispersal outside maternal home ranges is rare in much of British Columbia, so areas where all resident adult females have been killed are usually not recolonized (reviewed in MELP 1995, 1997; Cannings et al. 1999; Culling and Culling 2001).

Key factors limiting grizzly bear populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, wildlife management actions),
- habitat loss and alteration (clearing, fire suppression, reduced habitat effectiveness near human activity), and
- natural biotic and abiotic factors (severe weather, cannibalism by males).

3.3.5.1 Habitat Availability and Suitability

Habitat in the Blueberry area was rated as Moderate to Very Low capability (Class 3 to 5) for grizzly bear by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Current grizzly bear habitat suitability derived for the Blueberry Case Study is summarized in Table 11 and depicted in Figure 33.

Table 11. Current grizzly bear habitat suitability in the Blueberry study area (area classified as core in parentheses).

Analysis Unit	**Suitability Class**							
	High		**Moderate**		**Low**		**Nil**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Blueberry Overall	77 (38)	<1 (<1)	118,480 19,030	45 (7)	135,621 20,511	52 (8)	8,859 (278)	3 (<1)
Agriculture Settlement RMZ	3 1	<1 (<1)	45,832 (5,388)	49 (6)	44,368 (4,899)	48 (5)	2,920 (37)	3 (<1)
Alaska Highway RMZ	0 (0)	0 (0)	2,380 (4)	51 (<1)	1,751 (7)	38 (<1)	542 (0)	12 (0)
Grazing Reserve RMZ	0 (0)	0 (0)	4,316 (1,076)	48 (12)	4,340 (896)	48 (10)	415 (20)	5 (<1)
Jedney Enhanced Resource RMZ	74 (37)	<1 (<1)	65,952 (12,561)	42 (8)	85,162 (14,708)	55 (9)	4,982 (221)	3 (<1)

Approximately 45% of the Blueberry Case Study area is rated as Moderate or High suitability for grizzly bear. Like elk, most of this habitat is located in the southeast third of the study area (Figure 33) where mixedwood forests are more common (Figure 3).

3.3.5.2 Population Trends

Current and historical data on grizzly bear populations within MU 7-45, including the Blueberry Case Study Area, are absent. Anecdotal information suggests that grizzly bears are present throughout MU 7-45 at relatively low densities. Grizzly bear sightings and grizzly sign are not uncommon adjacent to oil and gas infrastructure in the northern portion of the Case Study area, and grizzly bear-livestock interactions are occasionally reported in agricultural lands in the southern portion (B. Culling, pers. obs.).

Harper (1988) indirectly estimated the grizzly bear population to be 1,172 in the Peace sub-region from compulsory inspection hunter harvest data. He also estimated that 62 grizzly bear occurred in MU 7-45, an average density of 1 bear/100 km^2. Excessive legal and illegal harvest exacerbated by access development was identified by (Harper 1988) as the only major impact on grizzly bear populations in the Peace sub-region. There is no evidence to indicate the direction of short- or long-term population trends within the Case Study area.

3.3.5.3 Cumulative Effects Evaluation

Development of cumulative effects assessment methods for grizzly bear began in the early 1980's and are now well established and generally accepted (Gibeau et al. 1996; Kansas 2002). These include three components: habitat effectiveness (integrating habitat availability, quality, and disturbance); mortality; and connectivity (linkage zone prediction). These methods, and established cumulative effects indicators and thresholds for grizzly bear were reviewed in Section 6.1.2 of Appendix 1.

Direct and indirect human-cause mortality appears to be the most significant factor affecting grizzly bear populations in western North America (Mattson 1993: ESGBP 1998; McLellan et al. 1999). Most grizzly bear mortality occurs within 500 m of roads and facilities and 200 m of backcountry facilities and trails (Mattson 1993; Gibeau et al. 1996; Mace et al. 1996; ESGBP 1998). Female survival is believed to be important for grizzly bear population persistence. Development activities that increase mortality of adult females may result in a reduction in grizzly bear populations (reviewed in Culling and Culling 2001). Because of their low productivity, grizzly bear populations respond slowly to impacts that produce a change in status.

In British Columbia, maximum sustainable harvest has been set at 4% of the estimated population, including kills from all sources. The unreported kill from natural mortality and accidental and illegal kills is standardized at 50% of the total kill unless documentation indicates otherwise. Total harvest should include no greater than 33% females, and hunting seasons are not permitted in management units with fewer than 26 bears (MELP 1995).

Annual grizzly bear sport harvest data from MU 7-45 (Figure 34) show that prior to 1998, total harvest, and female harvest exceeded the respective sustainable thresholds of 4% of the estimated MU population (2.7 bears) and 33% of total kill (0.67 females) in most years, excluding unreported kills.

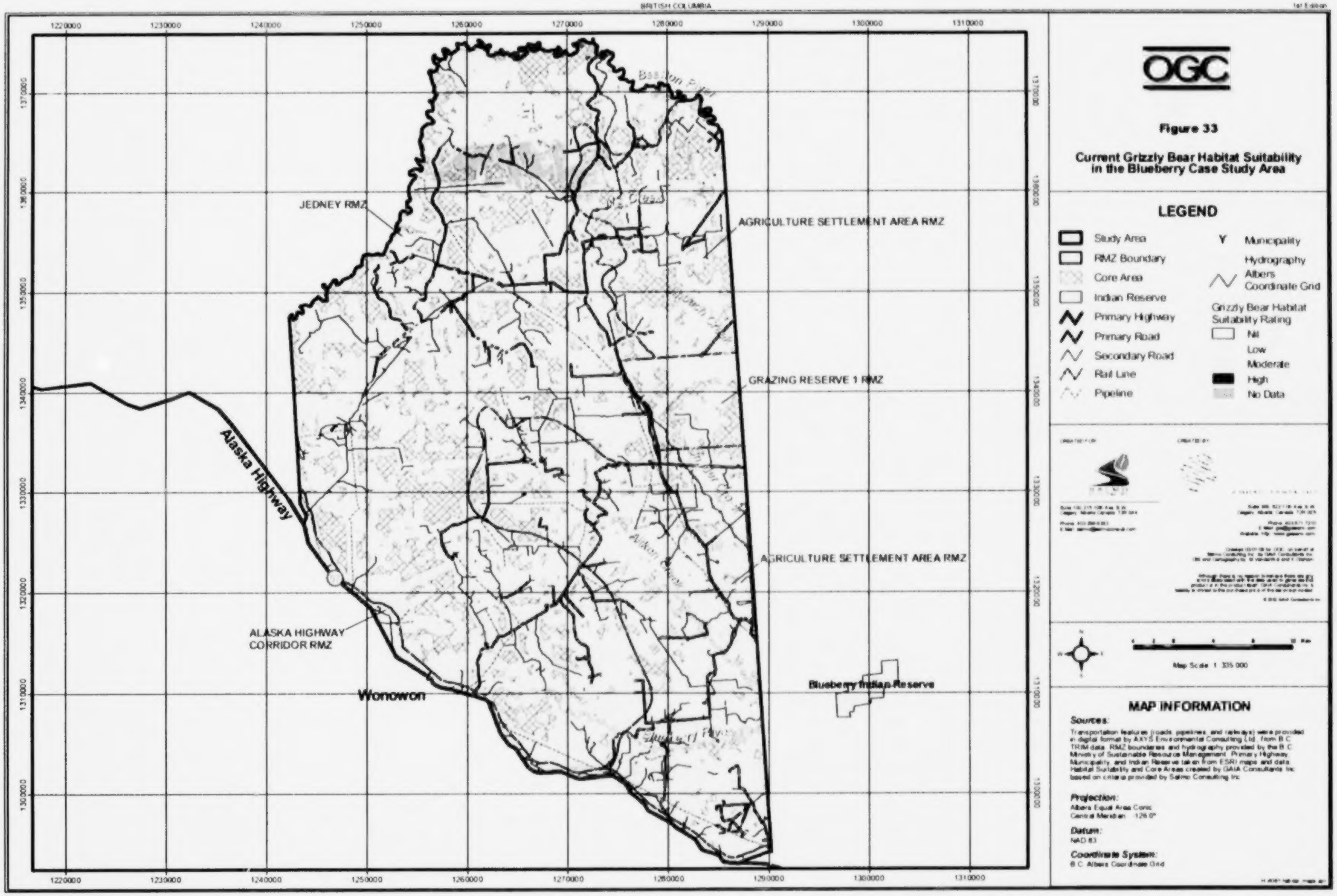

Figure 33

Current Grizzly Bear Habitat Suitability in the Blueberry Case Study Area

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:

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Coordinate System:

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Open road density thresholds of 0.45 to 0.6 km/km^2 have been established or proposed for bears in the Greater Yellowstone Grizzly Bear Recovery Zone (Servheen 1993). A threshold of 0.6 km/km^2 has also been identified to protect high quality grizzly bear habitat in British Columbia (BCF and MELP 1999a). Current road and trail density exceeds these established thresholds in the overall Blueberry Case Study area and all RMZs (Figure 9).

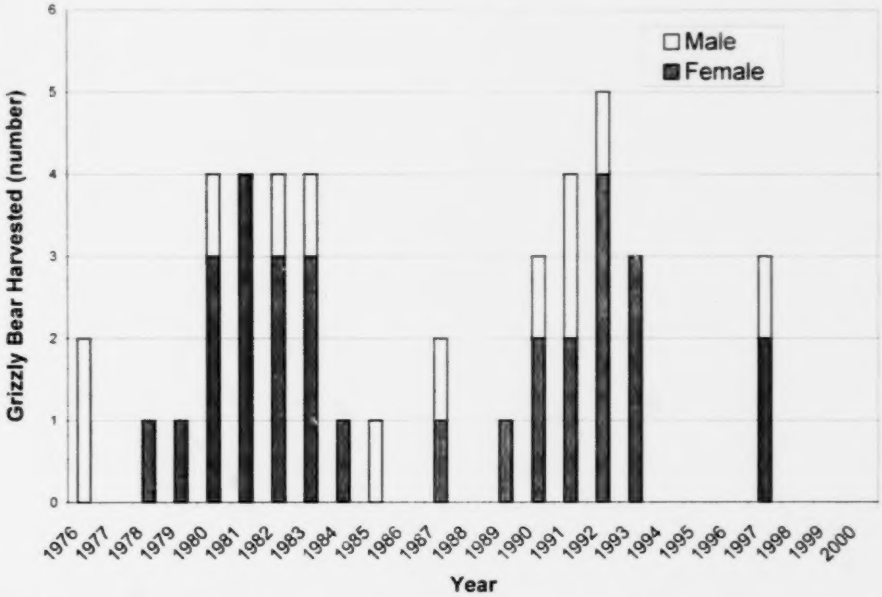

Figure 34. Annual grizzly bear harvest in Management Unit 7-45 (Blueberry Case Study area).

Minimum core area thresholds of >60% of available habitat have also been identified to ensure grizzly bear persistence in British Columbia (NCGBRT 2001) and elsewhere (Gibeau 2000). Remaining core area is well below this threshold in the overall Blueberry Case Study area and all RMZs (Table 11).

Insufficient data were available to directly examine the cumulative effect of development on grizzly bear abundance in the Blueberry Case Study area. However, mortality, habitat effectiveness, and core area analyses all indicate that persistence of a viable grizzly bear population in the Blueberry Case Study area is unlikely without continued immigration from less disturbed areas.

3.3.6 Other Wildlife

3.3.6.1 Deer

The majority of the Peace sub-region mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*) are concentrated in the Peace Lowlands ecosection, which has the mildest climate and lowest snow depths. Critical wintering habitat for mule deer is largely associated with southwest aspect shrub/grassland habitat along major river valleys such as the Peace, Beatton, and Halfway (core wintering habitat). White-tailed deer densities are highest in areas of moderate agricultural development. Deer are near the northern limit of their distribution in this area and abundance can fluctuate widely in response to winter severity. Deer are considered to have high ecological resilience because they have high reproductive potential and can recover quickly from population declines.

Habitat in the Blueberry Case Study area was rated as High to Moderate capability (Class 2 to 3) for mule and white-tailed deer by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Highest capability habitat occurs in larger river valleys.

The limited extent of suitable winter habitat restricts the distribution of deer within the Blueberry Case Study area. Radio-telemetry data have illustrated that the region's mule deer population is comprised of both migratory and resident subpopulations. During summer, migratory deer move from the core wintering habitat to outlying habitats, including those found in the Blueberry Case Study area. Resident mule deer winter in small areas of suitable habitat along the Beatton and Blueberry river escarpments. Harper (1988) estimated the mule deer population to be 11,500 in the Peace sub-region, and 400 within MU 7-45.

White-tailed deer are most abundant in the Agriculture/Settlement RMZ in the southeast portion of the Blueberry Case Study area, and are occasionally sighted throughout the remainder of the area. Harper (1988) estimated the sub-regional white-tailed deer population at 2,000 to 4,000, with no estimate for MU 7-45. Since Harper's 1988 estimate, populations within the Case Study area have likely increased as a result of a general range extension northward from the Peace Lowlands.

Deer harvest statistics for MU 7-45 are summarized in Figure 35. Total white-tailed deer harvest increased in the late 1980's following several mild winters (Figure 21) and has averaged 69 animals between 1990 and 2000. Mule deer harvest also increased in the late 1980's, but harvest levels have been affected by provincial government regulations adopted to reduce the harvest of mature mule deer bucks.

Clearing and agricultural conversion has probably improved habitat suitability for deer, although winter severity appears to be the primary factor limiting deer populations in the Blueberry Case Study area. Increased access and human development has increased mortality risk for both species, and harvest has affected population parameters of mule deer. Continued application of restrictive harvest regulations will likely be necessary to offset increased mule deer vulnerability.

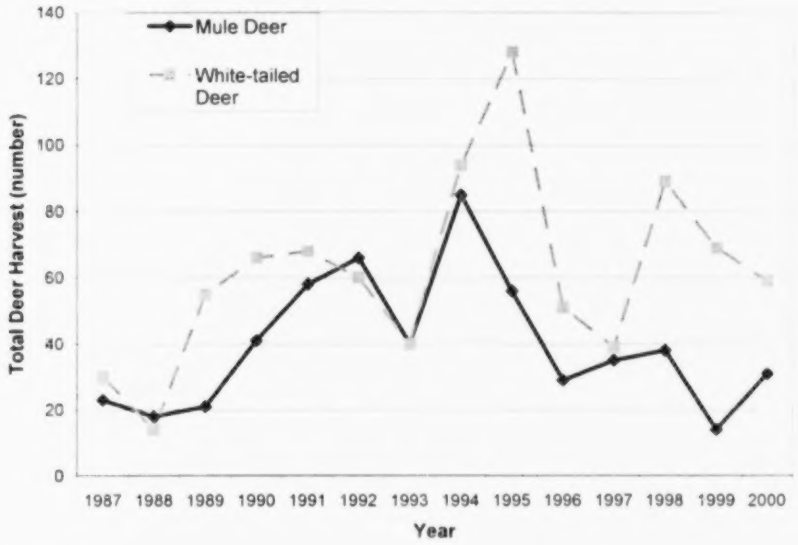

Figure 35. Total yearly harvest of mule deer and white-tailed deer in MU 7-45 (Blueberry Case Study area).

3.3.6.2 Gray Wolf (*Canis lupus*)

While the current distribution of the gray wolf in North America is much reduced from historic range and wolves are classified as endangered in the contiguous United States (Paquet and Hackman 1995), they are not considered either threatened or vulnerable in British Columbia. Wolf densities in northeast British Columbia are moderate to high (Culling and Culling 2001). Wolves are considered to have moderate ecological resilience because of their high reproductive potential and dispersal capabilities and ability to use a variety of prey species (Weaver et al. 1996).

Habitat in the Blueberry Case Study area was rated as Very High capability (Class 1) for wolf by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wolf, irrespective of current land use or seral stage.

Harper (1988) crudely estimated a wolf population of 520 in the Peace sub-region, and 42 to 56 animals in 7 packs in MU 7-45. This was calculated by extrapolating density estimates from other studies or by assuming pack size averaged 8 wolves per pack and 1 pack per major watershed. A substantial increase in wolf numbers was believed to have occurred in 1983 and 1984. Direct and indirect human mortality is the primary factor limiting wolf populations (reviewed in Weaver et al. 1996).

Combined human development and activity may have one of two effects on wolf distribution and abundance. Most researchers have found that wolves tend to avoid human settlements and areas with high levels of human activity (Thiel 1985; Jensen et al. 1986; Mech 1989; Thurber et al. 1994; Mladenoff et al. 1995; Whittington 2002). In these areas, wolves appear to select areas with road and trail densities less than 0.6 km/km^2.

This relationship does not appear to hold for less populated areas in the Canadian Rocky Mountains and boreal forest (reviewed in Jalkotzy et al. 1998 and Whittington 2002). Observations from northeast British Columbia and northwest Alberta also suggest that wolves may habituate to human activity if they are not harassed or persecuted (EES 1998, 1999 in Culling and Culling 2001). In these areas, wolf densities may increase as a result of human activity, and as described below, impacts on prey species are the cumulative effect of most concern.

Wolves are the chief predator of large mammals in northeast British Columbia (Harper 1988; Bergerud and Elliot 1998). Wolf densities in boreal systems appear to be sustained primarily by moose, with incidental predation on secondary prey species such as elk, caribou, and deer. Large scale or localized habitat alterations that result from combined development activities can increase the abundance of edge species such as moose, elk, and deer and support increased wolf densities (reviewed in Culling and Culling 2001). Increased wolf density has been shown to decrease density of both primary and secondary prey (Bergerud and Elliot 1998). Although no clear relationship has been demonstrated, the presence of roads, trails and cutlines may increase predation by providing packed travel surfaces or longer sight lines that increase wolf searching efficiency and range (Bergerud et al. 1984; Thurber et al. 1994; James 1999; James and Stuart-Smith 2000). This may be especially significant for woodland caribou because of their low ecological resilience (see Section 6.1.3 in Appendix 1).

Reported yearly trapper wolf harvest in MU 7-45 is summarized in Figure 36. Harvest over the last 15 years has been low and is inversely correlated with ungulate harvest, although correlation coefficients are low (-0.17 for elk, -0.29 for moose, -0.32 for white-tailed deer, and -0.49 for mule deer).

Insufficient data are available to directly examine the cumulative effect of development on wolf abundance in the Blueberry Case Study area. Available data do suggest that wolf have persisted in this area where road densities are above thresholds documented for more populated areas. This confirms observations from elsewhere in the Canadian Rocky Mountains and boreal forest.

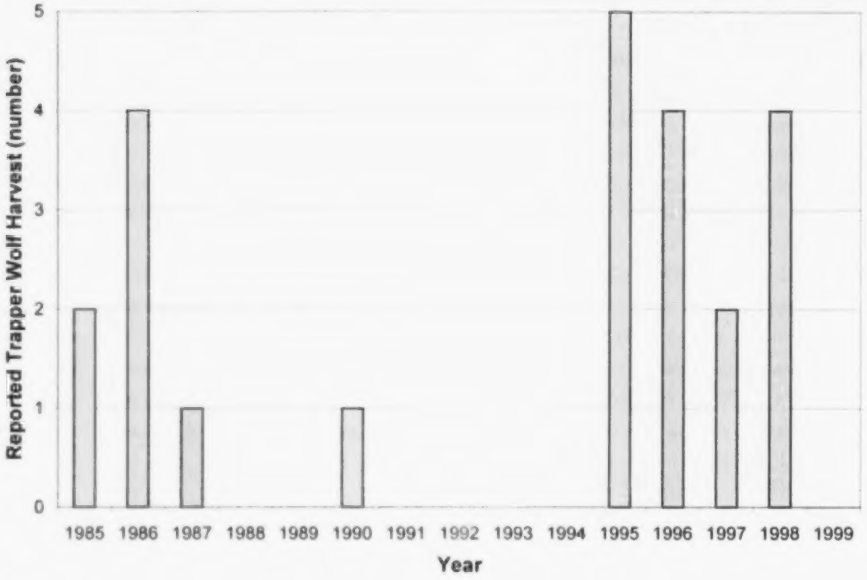

Figure 36. Trapper harvest of wolf in MU 7-45 (Blueberry Case Study area).

3.3.7 Fish

The Blueberry Case Study Area is almost entirely within the Beatton River watershed, a sub-basin of the Peace River watershed. Most (approximately 70%) of the Case Study area is drained by the Blueberry River and its tributaries, including the upper Blueberry River, Inglis Creek, Purslow Creek, Aitken Creek, North Aitken Creek, and the upper reaches of Snyder and Umbach creeks. The remainder is drained by direct tributaries to the Beatton River, the most significant of which is Nig Creek (16% of the study area). A small area (<0.5% of the study area) immediately adjacent to the Alaska Highway is within the Halfway River watershed, another sub-basin of the Peace River.

The Blueberry River and adjacent portions of the Beatton River watershed, including Nig Creek, are low-gradient, high-turbidity systems located within the Boreal Plains ecoprovince well to the east of the Rocky Mountain Foothills. Streams within the case study area typically originate on well-drained, undulating terrain and flow eastward toward the Beatton River mainstem at gradients of 1% to 3%. Watercourse banks and valley slopes generally exhibit a high degree of natural instability resulting in frequent slumping and associated high suspended solids levels. Streambed substrates are generally composed of cobble and gravel, with a significant proportion of fines. Habitat typically consists of riffle-pool configurations with rearing cover provided primarily by deep pools, large woody debris, turbidity and tanic colouration.

Existing fisheries information suggests that aquatic habitats within the Blueberry Case Study Area support a diversity of forage fish species. Past sampling within the case study area has identified nine non-sport species including, lake chub (*Couesius plumbeus*), spoonhead sculpin (*Cottus ricei*), slimy sculpin (*Cottus cognatus*), longnose sucker (*Catostomus catostomus*), white sucker *(Catostomus commersoni)*, longnose dace

(*Rhinichthys cataractae*), troutperch (*Percopsis omiscomaycus*), redside shiner (*Richardsonius balteatus*), and flathead chub *(Platygobio gracilis)*.

Two sport-fish species are known to occur within the study area: northern pike, and Arctic grayling. Recreational angling opportunities within the Blueberry Case Study area are severely restricted by low sport-fish densities resulting from low habitat suitability, small maturation size, and high turbidity.

3.3.7.1 Northern Pike (*Esox lucius*)

Northern pike is a coolwater species with high recreational and economic value in some areas. It is relatively sedentary, a top predator, grows slowly, and has a high age at maturity. As such, it is sensitive to contaminant bioaccumulation, harvest pressure, and habitat alteration (loss of aquatic vegetation) and is considered to have moderate ecological resilience (reviewed in Ursus and Salmo 2002).

Northern pike appear to be present at low densities in the Blueberry Case Study area. Their distribution is limited to the lower and middle Beatton and Blueberry river mainstems and the lower reaches of larger tributaries, including Aitken Creek and Nig Creek.

In the Blueberry Case Study area, natural environmental changes (e.g., drought, flooding, sudden cold spells) will affect northern pike reproductive success, recruitment, and survival. Sources of cumulative effects on this species include harvest, loss of aquatic vegetation and instream cover, and changes in water quality. No harvest or population data are available for this area, but sport harvest is assumed to be negligible to low. Most habitat loss and alteration and changes in water quality have occurred in the Agriculture/Settlement RMZ as a result of agricultural land conversion. However, watershed indicators for this RMZ indicate that the current cumulative effects hazard level is Low (Section 3.2.4). Insufficient data were available to examine the effect of watershed development on northern pike distribution or abundance.

3.3.7.2 Arctic Grayling (*Thymallus arcticus*)

Arctic grayling is a coldwater species that is very sensitive to fishing pressure and habitat alteration. Grayling distribution appears to be limited by mid-summer temperature regime, and appears to follow elevation and temperature isotherms (O'Neil and Patalas 2001). In British Columbia, some populations are in severe decline and have been identified as a species 'requiring special forestry considerations' (Haas 1998). Some Arctic grayling populations migrate large distances between spawning, feeding, and overwintering areas; small streams with clean substrate are required for spawning (reviewed in Ford et al. 1995). Grayling are considered to have low ecological resilience due to ease of capture, low annual production, high natural mortality, short lifespan, limited reproductive capacity, limited critical habitat availability, susceptibility to movement barriers, and significant year-to-year climatic influence (reviewed in Ursus and Salmo 2002).

The Fort St. John LRMP makes specific reference to grayling, suggesting that they "appear to be diminishing in presence and population size in many watersheds" (FSJ LRMP 1997). Fisheries sampling data suggests that the upper Blueberry River watershed supports a very limited Arctic grayling population. Only two occurrences of Arctic grayling have been recorded; both involved low densities of rearing juveniles. The first was in Inglis Creek (DES 1993), and the second in an unnamed tributary at the headwaters of the Blueberry mainstem (Triton 1994). Suitability for Arctic grayling appears somewhat higher in Nig Creek, and historical sampling results suggest the presence of higher seasonal densities of rearing juveniles. There is no evidence that Arctic grayling within the Case Study area have a migratory life form. Grayling in the upper Blueberry River and Nig Creek are assumed to be two of several resident subpopulations within the upper Beatton River drainage.

In the Blueberry Case Study area, natural environmental changes (e.g., drought, beaver dams, spring water temperatures) will affect grayling reproductive success, recruitment, and survival. Sources of cumulative effects on this species include harvest, siltation effects on spawning and juvenile rearing habitat, and the exclusion of juvenile grayling from seasonal rearing habitat through the creation of barriers at road and pipeline crossings. Watershed indicators indicate that current cumulative effects hazard level is Low in watercourses of the Blueberry Case Study area (Section 3.2.4). Insufficient data were available to examine the effect of watershed development on Arctic grayling distribution or abundance.

4. CUMULATIVE EFFECTS INDICATORS AND THRESHOLDS

Cumulative effects management is largely focused on defining how and where human activities can be continued without irreversible net harm to habitat, fish and wildlife populations, or biodiversity. Most cumulative effects ultimately result from the combined effects of small routine projects or activities. Nevertheless, the potential cumulative effects of these everyday activities are rarely considered in a formal way. This is at least partly due to the perception that complex, expensive, and time-consuming technical methods such as species-specific habitat modelling are required. Available literature and practice in other jurisdictions demonstrates that cumulative effects indicators can be used to quickly and economically assess the probability of adverse cumulative effects.

A suite of complementary land use and habitat indicators was identified as the most appropriate for assessing and managing cumulative effects on fish and wildlife habitat and populations in northeast British Columbia (Appendix 1). These indicators quantify the area affected directly and indirectly by access corridors and the number and size of relatively undisturbed areas. They are:

Land Use Indicators

1. Access density (km of linear corridors per unit area).
2. Stream crossing index (number of crossings per km of stream).
3. Activity setbacks.

Habitat Indicators

1. Core area (% of analysis area).
2. Patch and corridor size (area in ha or width in m).
3. No Net Habitat Loss.

4.1 APPLICABILITY OF LAND USE AND HABITAT INDICATORS

This section evaluates the suitability of recommended land use and habitat indicators for cumulative effects assessment and management in northeast British Columbia based on data from the Blueberry Case Study area.

4.1.1 Access Density

Access density is considered to be a useful land use indicator because it integrates the many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance (Forman and Hersperger 1996). Road and trail density and combined land use and habitat indicators provided statistically significant ($p<0.05$) predictions of moose harvest in the Blueberry Case Study area (Section 3.3.2 in this report).

Current access corridor densities exceed established and derived thresholds for caribou (Section 3.3.3; Section 6.1.3 in Appendix 1). This is consistent with observations that woodland caribou no longer use the Blueberry Case Study area but were assumed to be present at low densities prior to intensive development. Total corridor density exceeds the 1.8 to 3 km/km^2 thresholds identified for woodland caribou persistence. Combined road and trail density exceeds the value at which northern-ecotype caribou moved from traditional winter range. ALCES landscape simulations indicate that the Blueberry Case Study area provided no effective habitat for caribou by 1980 due to indirect effects of access corridor construction and clearing. Development trends generated using historical data for this area demonstrate that access density thresholds were exceeded in the early 1970's. These independent analyses all conclude that cumulative effects risk is elevated for woodland caribou and that they are unlikely to persist in the Blueberry Case Study area.

Average road and trail density is a good predictor of remaining core area in the Blueberry Case Study area (Figure 37). The availability of relatively undisturbed core areas decreases exponentially as road and trail density increases. In the Blueberry study areas, 60%, 40%, 30%, and 10% core area thresholds identified in Appendix 1 (Section 4.1.4) correspond to average road and trail densities of 0.4 km/km^2, 0.72 km/km^2, 0.97 km/km^2, and 1.82 km/km^2, respectively.

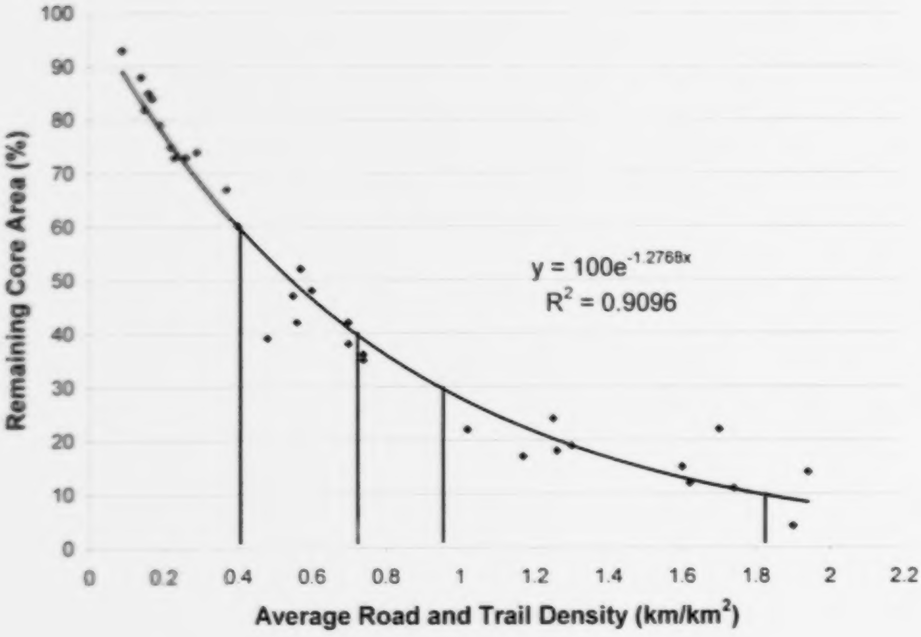

Figure 37. Relationship between road and trail density and remaining core area.

Although road and trail density appears to be a practical cumulative effects indicator, the Case Studies also demonstrate that documented relationships between road density and response of large wildlife species may not be directly applicable to northeast British Columbia. Animal response to habitat and disturbance features such as roads can be considered at two scales of analysis. At the regional scale, individuals or groups select home ranges or territories that meet all their life history need (2nd order selection). Within this home range or territory, individuals and groups select or avoid areas based on site-specific features (3rd order selection; Rettie and Messier 2000; Apps et al. 2001; Szkorupa 2002). For example, wolf packs appear to select areas with low road densities and low densities of humans in populated landscapes. In many remote areas however, wolves appear to use, or select areas close to roads, trails, and cutlines. This suggests that it is not the physical feature the road represents that wolves avoid, but the positive correlation between road density and number of encounters with humans (reviewed in Whittington 2002). Prey species, including moose, caribou, and elk, appear to respond to disturbance in the opposite manner (Dyer 1999; Schneider and Wasel 2000), presumably to reduce the risk of wolf predation.

Northeast British Columbia has relatively low road and population densities when compared with most locations where road density effects have been studied. O'Neill (1993) estimated that 20% of cutlines in the region were passable by four-wheel drive vehicles, but concluded that actual use of these linear features was low. This is similar to findings in areas of the Alberta foothills with similar population density (Kansas and Collister 1999; Salmo unpub. data).

In addition, as noted in Appendix 1 (Section 2.3.4), physiological and behavioural responses of individuals may not be translated into reductions in animal numbers, particularly for species with high reproductive rates, species able to habituate to repeated disturbance (e.g., elk), or populations adjacent to protected or wilderness areas. For example, established models (Section 2.3.3 in Appendix 1) predict that elk habitat effectiveness in the Blueberry Case Study area has been reduced by more than 45% due to construction of roads and trails (Section 3.3.4 in this report). Realized reductions in habitat effectiveness have not affected local populations however, as the expansion of the road and trail network has coincided with a dramatic increase in elk populations in these areas. O'Neill (1993) also concluded that loss in habitat effectiveness is not a significant issue for many species in this region.

Another issue relates to the way in which road or access density indicators are calculated. Most documented road density relationships and thresholds are based on average (mean) values. The average value is a measure of central tendency and is most applicable to samples with a symmetrical or normal (e.g., bell curve) distribution. When samples are asymmetrical or skewed however, calculated average road density is greatly influenced by extremely high values. In these cases, the median (middle measurement) is the preferred method to describe central tendency (Zar 1984).

Figure 38 presents access density values calculated for 1 km^2 'cells' in the Blueberry Case Study area. Because road and trail curves are skewed to the left, calculated average road and trail densities are much larger than calculated median densities. This discrepancy is greatest at earlier stages of fragmentation, as observed in the Sukunka Case Study area (Appendix 3). In addition, moving window analyses are particularly sensitive to boundary effects (Ake 1995), which can further bias average values. As linear features and associated fragmentation increase, the frequency distribution becomes more symmetrical. For example, when all corridors in the Blueberry area were combined, the current average (5.9 km/km^2) and median (5.2 km/km^2) were closer (Figure 38).

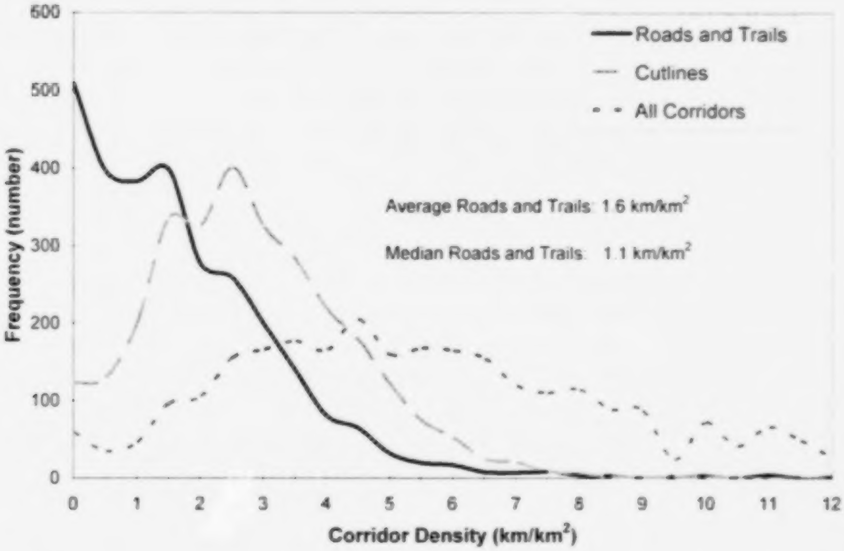

Figure 38. Current linear feature frequency in the Blueberry Case Study area.

The Blueberry Case Study confirms that access density can be used to document cumulative effects risk in northeast British Columbia. In this study, median road and trail density was the indicator that best predicted moose harvest, and was a better predictor than average density. Although average access density is the normal reporting convention, use of median access density is considered to be more appropriate in forested areas of northeast British Columbia.

4.1.2 Stream Crossing Index

The stream crossing index is an indicator of potential sources of sediment, mortality, and barriers to movement. It provides the most direct indicator of aquatic cumulative effects risk because it includes only features that intersect watercourses (Section 5.5.6 in Appendix 1).

Stream crossing indices were calculated for all subwatersheds in the Blueberry Case Study area using TRIM II hydrography. Stream crossing indices for these areas were very low relative to other foothills areas (Alliance 1997; Salmo 1999, 2000, unpub. data), and a comparative analysis was undertaken using readily available 1:50,000 scale digital hydrography data (Table 12). The TRIM II hydrography layer included over 300% more 'streams' in the Blueberry Case Study area than the 1:50,000 hydrography layer (6,521 km vs. 2,016 km). Smaller scale (1:50,000) hydrography data are considered to be most appropriate for this indicator because they more accurately identify potential fish-bearing watercourses.

Table 12. Comparison between current watershed indices generated with TRIM II and 1:50,000 scale hydrography data for the overall Blueberry Case Study area.

Indicator	TRIM II Value	1:50,000 Value
Stream Crossing Index (#/km^2)		
Primary Roads	0.07	0.05
Secondary Roads	0.08	0.08
Truck Trails	0.45	0.37
Pipelines	0.04	0.04
Railway Lines	0.01	0.01
Cutlines	1.24	1.19
Total	1.83	1.68
Riparian Roads (#/km)		
Primary Roads	0.014	0.026
Secondary Roads	0.019	0.040
Truck Trails	0.132	0.221
Total	0.164	0.287
Riparian Area Cleared (% of area)		
Primary Roads	0.06	0.4
Secondary Roads	0.09	0.7
Truck Trails	0.23	1.5
Pipelines	0.04	0.3
Railway Lines	0.01	0.1
Cutlines	0.50	4.4
Clearings	1.07	16.1
Total	2.06	23.7

Watershed riparian indicators calculated with 1:50,000 hydrography data were significantly ($P<0.01$) higher than those calculated with TRIM II data – this elevated riparian risk in the Case Study area from Low to High. Stream crossing indices calculated with smaller scale data were significantly lower than those calculated with TRIM II data.

Insufficient data on fish abundance and distribution were available to confirm the applicability of stream crossing index predictions of potential cumulative effects risk in the Blueberry Case Study area.

4.1.3 Core Area

Remaining core area is considered to be one of the most practical cumulative effects indicators and has been widely used for grizzly bear and other species (reviewed in Section 4.1.4 of Appendix 1). This habitat index provides a useful complement to access density by identifying the availability and location of areas where minimal human impacts have occurred. In fragmented landscapes, these areas have increased importance for population persistence; application of a minimum core area indicator can help minimize further fragmentation.

Loss of core area occurred at a much higher rate than did clearing, reflecting the non-linear nature of edge effects (Figure 39). In the Blueberry Case Study area, the rate at which core area was lost was roughly linear over the fifty year evaluation period. Theoretical fragmentation models and studies in other areas have identified critical changes at around 40% to 60% core area for habitat specialists such as woodland caribou and interior forest songbirds.

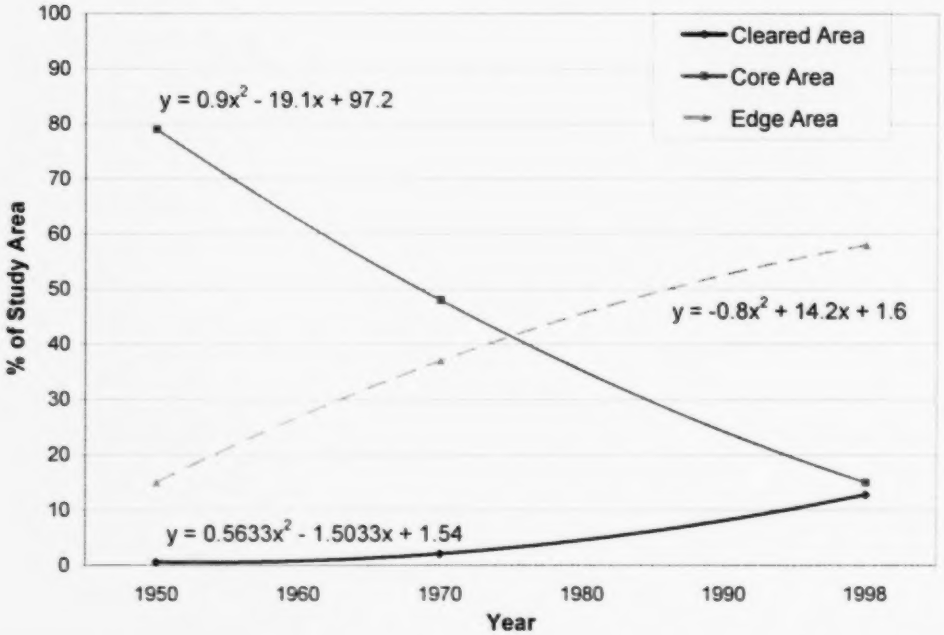

Figure 39. Trends in clearing, edge and core in the Blueberry Case Study area.

A generally accepted cumulative effects method has been developed to calculate core security areas for grizzly bear (e.g., Gibeau et al. 1996, Appendix 1). This method requires information on seasonal habitat suitability, disturbance features, and assumed or actual human use of these features on a seasonal basis. This method has recently begun to be applied to a variety of other large mammals, including moose. In the Blueberry Case Study, generalized core area availability was found to have equal predictive power for a moose population index as the more detailed (and costly) indicator that integrated habitat suitability (Section 3.3.2). This indicates that core area can be used as a generalized landscape indicator for tolerant habitat generalists such as moose and elk. More detailed, species-specific evaluations will be required for intolerant or sensitive species, such as woodland caribou, that rely on relatively large and isolated patches of habitat with specific seral or structural attributes for persistence.

4.1.4 Patch and Corridor Size

Insufficient data on species abundance and distribution were available to test effects of patch and corridor size. In both case study areas, core areas changed from a few very large contiguous patches to a many fragments over the 30 to 50 year analysis period. Smaller fragments provide limited security for large or intolerant species, so patch and corridor size should be integrated into core area analyses to quantify those areas with value for focus species.

Figure 40 provides an ALCES simulation of average forest patch size between 1950 and 2050. Between 1950 and the present, average patch size has decreased by approximately 60% based on actual clearing and access construction trends. Three future scenarios were modeled: Low growth (line 1 = growth continues at actual 1950 to 1998 development rate), Moderate growth (line 2 = growth continues at actual 1970 to 1998 average development rate), and High growth (line 3 = growth continues at actual 1970 to 1998 average development rate plus 20%). Projected future trends in forest patch size are not highly sensitive to the growth rate used. In all cases, the average forest patch will be approximately 50% smaller in 2050.

Figure 41 displays the change in calculated core area size for the Blueberry Case Study area between 1950 and the present. In 1950, most core area was included in a several very large, contiguous patches. Since that time, core area has been fragmented into many small patches. Smaller fragments (<100 ha) provide limited security for large or intolerant species such as ovenbird (*Seiurus aurocapillus*), marten (*Martes americana*), grizzly bear, and wolverine (*Gulo gulo*). Very small fragments (<4.5 ha) provide limited security for small intolerant species, including most interior forest songbirds (reviewed in Section 4.1 of Appendix 1).

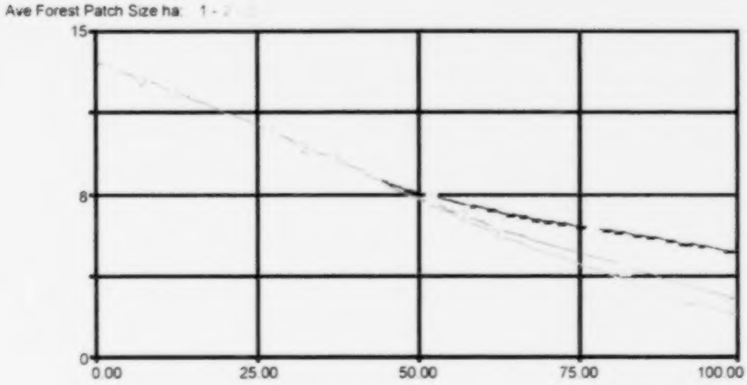

Figure 40. Simulated trends in forest patch size in the Blueberry Case Study area (average forest patch size (ha) on y-axis; 1 = Low growth scenario, 2 = Average growth scenario, 3 = High growth scenario).

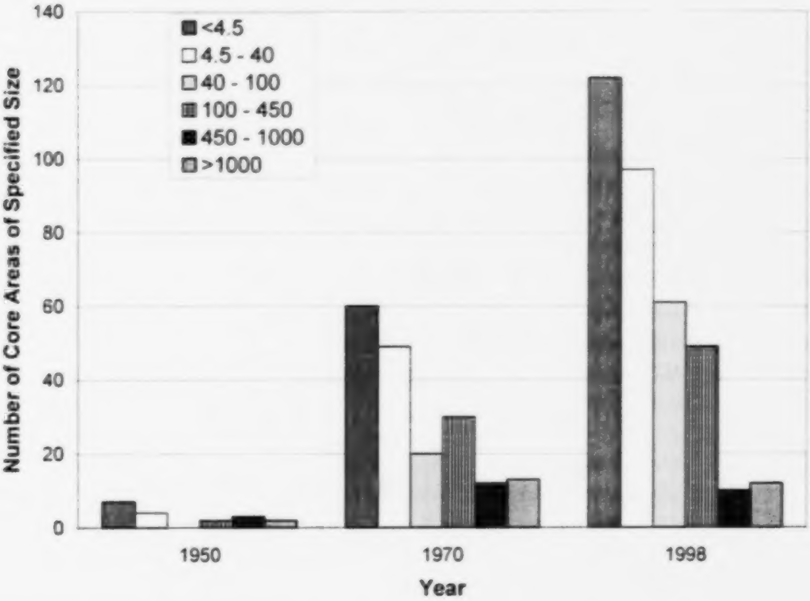

Figure 41. Core area size distribution in the Blueberry Case Study area.

4.1.5 Utility of Existing Data

The Case Studies also evaluated the utility of readily available data for use in cumulative effects models and assessments. For reasons summarized below, the availability and quality of existing data affected study conclusions.

The readily available TRIM II digital data provided to be insufficient to accurately identify disturbance features. Most significantly, many clearings are not identified, so it is impossible to distinguish industrial, commercial, and recreational facilities from forest cutblocks, houses, and agricultural fields. In addition, information on the age of the feature, reclamation status, and intensity of use is not available; this is critical for differentiating between high-use and low- or no-use features.

Existing forest cover data available from the British Columbia Provincial Government are known to be inaccurate and do not include insufficient information to develop reliable habitat suitability ratings. The Provincial Government is currently developing wildlife habitat maps based on the 1:250,000 Broad Terrestrial Ecosystem Classification scheme (BEI; RIC 1998) that are designed to be more suitable for cumulative effects analyses. In addition, medium to large scale Terrestrial Ecosystem Mapping (TEM; RIC 1999) is available for some areas. Use of these maps would enhance the consistency and accuracy of habitat suitability ratings and also reduce the cost to those evaluating cumulative effects.

Analyses of watershed indicators are sensitive to the scale of the hydrography layer used. The readily available TRIM II digital data includes numerous computer-generated watercourses that do not occur in the field. This causes critical stream-length based indicators (riparian area cleared, stream crossing index) to be inaccurate (Table 12). For this reason, watershed indicators should be calculated using the 1:50,000 watershed polygons and stream network provided in the British Columbia Watershed Atlas.

Finally, the evaluation of relationships between development and renewable resource trends was primarily hindered by the lack of data on species abundance and distribution. In particular, the original plan to include a Case Study in a muskeg-dominated area important for woodland caribou could not be achieved due to a lack of information on the boreal ecotype in this region.

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APPENDIX A

TERRESTRIAL AND AQUATIC DISTURBANCE FEATURES: 1950, 1970, CURRENT

1950 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No.	Average Size (ha)	Range (ha)					
		min.	max.	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min.	max.	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Study Area																	
Primary Roads	0.05	0.00	2.88	272.9	0.1	14150.0	5.3							0.01	0.006	6.8	0.1
Secondary Roads	0.05	0.00	5.50	222.1	0.1	12711.8	4.7							0.01	0.005	6.0	0.1
Truck Trails	0.09	0.00	4.90	190.4	0.1	11240.2	4.2							0.04	0.022	9.1	0.2
Pipelines	0.01	0.00	1.33	40.7	0.0	827.2	0.3							0.00		2.3	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.34	0.00	20.19	736.9	0.3	0.0	0.0							0.17		36.3	0.6
Communities				20.9	0.0	72.8	0.0									0.0	0.0
Wellsites				11.9	0.0	200.0	0.1									0.1	0.0
Clearings				217.8	0.1	216.6	0.1									19.3	0.3
Existing Total	**0.19[7]**	**0.00[7]**	**12.42[7]**	**1713.6**	**0.6**	**39418.5**	**14.7**	**210877**	**79**	**16**	**13179.8**	**0.0**	**203428**	**0.24[8]**	**0.033[9]**	**80.0**	**1.3**
Jedney RMZ																	
Primary Roads	0.04	0.00	1.66	142.4	0.1	7203.1	4.5							0.01	0.006	3.8	
Secondary Roads	0.03	0.00	2.09	83.1	0.1	5086.3	3.2							0.01	0.003	2.6	
Truck Trails	0.08	0.00	4.63	103.9	0.1	6169.1	3.8							0.04	0.020	5.8	
Pipelines	0.01	0.00	1.33	37.8	0.0	827.2	0.5							0.01		2.1	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.28	0.00	3.07	373.1	0.2	0.0	0.0							0.15		20.3	
Communities				0.0	0.0	21.1	0.0									0.0	
Wellsites				9.3	0.0	148.2	0.1									0.1	
Clearings				217.8	0.1	216.6	0.1									19.3	
Existing Total	**0.15[7]**	**0.00[7]**	**4.63[7]**	**967**	**0.6**	**19671**	**12**	**130825**	**82**	**8**	**16353.1**	**0.1**	**127284**	**0.22[8]**	**0.029[9]**	**54.02**	
Agriculture Settlement Area RMZ																	
Primary Roads	0.07	0.00	1.65	126.5	0.1	6453.0	6.9							0.02	0.009	3.1	
Secondary Roads	0.05	0.00	2.09	96.0	0.1	5514.2	5.9							0.02	0.006	2.8	
Truck Trails	0.10	0.00	3.95	68.3	0.1	4315.4	4.6							0.04	0.024	3.1	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.43	0.00	20.19	319.0	0.3	0.0	0.0							0.21		14.5	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				2.6	0.0	51.8	0.1									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.22[7]**	**0.00[7]**	**3.95[7]**	**612**	**0.7**	**16334**	**17**	**70770**	**75**	**13**	**5443.9**	**0.0**	**39326**	**0.28[8]**	**0.039[9]**	**23.44**	

[1] Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).

[2] Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

[3] Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

[4] Percent (%) of specified area, excluding lakes.

[5] Includes linear features within 100 m of a stream.

[6] Includes all cleared areas within 15 m of a waterbody.

[7] Total corridor density includes roads and truck trails.

[8] Total stream crossings include roads, truck trails, pipelines, and cutlines.

[9] Total valley roads include roads and truck trails.

[10] Percent of total riparian area.

1950 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Grazing Reserve 1 RMZ																	
Primary Roads	0.08	0.00	1.25	0.0	0.0	292.3	3.3							0.00	0.000	0.0	
Secondary Roads	0.05	0.00	1.05	9.3	0.1	521.9	5.9							0.00	0.000	0.0	
Truck Trails	0.03	0.00	0.85	2.6	0.0	199.3	2.2							0.01	0.010	0.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.46	0.00	2.78	36.8	0.4	0.0	0.0							0.26		1.3	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.16[7]**	**0.00[7]**	**1.34[7]**	**49**	**0.5**	**1013**	**11**	**7525**	**85**	**1**	**7525.0**	**7525.0**	**7525**	**0.27[8]**	**0.010[9]**	**1.33**	
Alaska Highway Corridor RMZ																	
Primary Roads	0.06	0.00	2.88	3.9	0.1	201.6	4.3							0.00	0.000	0.0	
Secondary Roads	0.27	0.00	5.50	33.8	0.7	1589.4	34.0							0.09	0.033	0.6	
Truck Trails	0.36	0.00	4.90	15.6	0.3	556.4	11.9							0.11	0.058	0.3	
Pipelines	0.01	0.00	1.00	2.9	0.1	0.0	0.0							0.01		0.2	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.22	0.00	3.64	8.0	0.2	0.0	0.0							0.05		0.1	
Communities				20.9	0.4	51.7	1.1									0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.70[7]**	**0.00[7]**	**12.42[7]**	**85**	**1.8**	**2399**	**51**	**1757**	**38**	**25**	**70.3**	**0.0**	**365**	**0.27[8]**	**0.091[9]**	**1.18**	
Beatton River Watershed																	
Primary Roads	0.01	0.00	1.12	1.4	0.0	140.2	0.4							0.00	0.000	0.0	0.0
Secondary Roads	0.02	0.00	1.42	5.4	0.0	450.7	1.4							0.00	0.002	0.2	0.0
Truck Trails	0.07	0.00	4.90	12.0	0.0	711.4	2.2							0.02	0.012	0.6	0.1
Pipelines	0.00	0.00	1.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.16	0.00	2.31	50.2	0.2	0.0	0.0							0.08		2.0	0.3
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				1.3	0.0	3.9	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.09[7]**	**0.00[7]**	**4.90[7]**	**70**	**0.2**	**1306**	**4**	**30526**	**93**	**7**	**4360.9**	**0.0**	**30469**	**0.11[8]**	**0.014[9]**	**2.76**	**0.4**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1950 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²) min	Range (km/km²) max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	Total ha	Total (% of area)[4]	No.	Average Size (ha)	Range (ha) min	Range (ha) max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Nig Creek Watershed																	
Primary Roads	0.06	0.00	1.66	47.0	0.1	2352.5	5.5							0.01	0.005	0.8	0.1
Secondary Roads	0.02	0.00	1.08	17.9	0.0	1114.3	2.6							0.01	0.004	0.9	0.1
Truck Trails	0.06	0.00	4.63	19.7	0.0	849.7	2.0							0.01	0.008	0.4	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.22	0.00	2.94	73.2	0.2	0.0	0.0							0.11		3.2	0.3
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.14[7]**	**0.00[7]**	**4.63[7]**	**158**	**0.4**	**4317**	**10**	**37357**	**88**	**4**	**9339.2**	**34.0**	**21460**	**0.14[8]**	**0.017[9]**	**5.24**	**0.47**
Aitken Creek Watershed																	
Primary Roads	0.10	0.00	1.66	156.2	0.2	7824.8	9.7							0.03	0.015	4.7	0.3
Secondary Roads	0.05	0.00	1.72	71.2	0.1	3838.2	4.7							0.01	0.004	1.8	0.1
Truck Trails	0.09	0.00	2.32	56.5	0.1	3617.0	4.5							0.04	0.020	2.9	0.2
Pipelines	0.00	0.00	0.22	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Seismic Lines	0.39	0.00	3.07	246.3	0.3	0.0	0.0							0.18		12.2	0.7
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Well Sites				5.5	0.0	82.9	0.1									0.0	0.0
Clearings				217.8	0.3	216.6	0.3									19.3	1.1
Existing Total	**0.23[7]**	**0.00[7]**	**2.63[7]**	**754**	**0.9**	**15580**	**19**	**58856**	**73**	**17**	**3462.1**	**0.2**	**56472**	**0.26[8]**	**0.039[9]**	**40.95**	**2.3**
Umbach Creek Watershed																	
Primary Roads	0.08	0.00	1.64	23.2	0.1	1267.9	4.6							0.02	0.004	0.7	0.1
Secondary Roads	0.04	0.00	1.05	16.7	0.1	946.6	3.5							0.00	0.001	0.1	0.0
Truck Trails	0.05	0.00	1.67	12.4	0.0	845.3	3.1							0.03	0.014	0.5	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.58	0.00	20.19	123.4	0.5	0.0	0.0							0.31		6.1	1.0
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.17[7]**	**0.00[7]**	**2.27[7]**	**176**	**0.6**	**3060**	**11**	**23092**	**84**	**2**	**11546.0**	**5697.6**	**17394**	**0.36[8]**	**0.019[9]**	**7.33**	**1.2**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.
4 Percent (%) of specified area, excluding lakes.
5 Includes linear features within 100 m of a stream.
6 Includes all cleared areas within 15 m of a waterbody.
7 Total corridor density includes roads and truck trails.
8 Total stream crossings include roads, truck trails, pipelines, and cutlines.
9 Total valley roads include roads and truck trails.
10 Percent of total riparian area.

1950 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²) min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	Total ha	Total (% of area)[4]	No	Average Size (ha)	Range (ha) min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Creek Watershed																	
Primary Roads	0.03	0.00	2.88	37.8	0.0	2197.9	2.7							0.00	0.002	0.6	0.0
Secondary Roads	0.08	0.00	5.50	99.2	0.1	5927.7	7.2							0.02	0.008	2.7	0.2
Truck Trails	0.15	0.00	4.90	85.1	0.1	5077.0	6.2							0.07	0.037	4.6	0.3
Pipelines	0.02	0.00	1.33	40.7	0.0	827.2	1.0							0.01		2.3	0.1
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.36	0.00	3.64	234.2	0.3	0.0	0.0							0.18		12.5	0.7
Communities				20.2	0.0	68.6	0.1									0.0	0.0
Wellsites				5.0	0.0	113.2	0.1									0.1	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.26[7]**	**0.00[7]**	**12.42[7]**	**522**	**0.6**	**14212**	**17**	**59918**	**73**	**14**	**4279.8**	**0.0**	**36203**	**0.28[8]**	**0.046[9]**	**22.78**	**1.3**
Misc Lower Beatton River Watershed																	
Primary Roads	0.33	0.00	1.46	6.4	0.7	300.8	31.9							0.14	0.046	0.1	1.9
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Truck Trails	0.03	0.00	0.76	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	1.05	0.00	3.28	6.8	0.7	0.0	0.0							0.63		0.3	3.8
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.37[7]**	**0.00[7]**	**1.52[7]**	**13**	**1.4**	**301**	**32**	**634**	**67**	**2**	**316.9**	**0.0**	**634**	**0.70[8]**	**0.046[9]**	**0.43**	**5.6**
Lower Peace River Watershed																	
Primary Roads	0.06	0.00	1.46	0.0	0.0	36.1	3.4							0.00	0.000	0.0	0.0
Secondary Roads	0.32	0.00	2.09	8.7	0.8	361.7	33.7							0.21	0.040	0.3	2.7
Truck Trails	0.31	0.00	3.95	2.7	0.2	118.6	11.1							0.11	0.039	0.1	0.5
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.24	0.00	3.57	1.0	0.1	0.0	0.0							0.00		0.0	0.0
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.69[7]**	**0.00[7]**	**3.95[7]**	**12**	**1.2**	**516**	**48**	**472**	**44**	**5**	**94.3**	**0.6**	**355**	**0.32[8]**	**0.079[9]**	**0.37**	**3.2**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.
4 Percent (%) of specified area, excluding lakes.
5 Includes linear features within 100 m of a stream.
6 Includes all cleared areas within 15 m of a waterbody.
7 Total corridor density includes roads and truck trails.
8 Total stream crossings include roads, truck trails, pipelines, and cutlines.
9 Total valley roads include roads and truck trails.
10 Percent of total riparian area.

1970 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min.	max.	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Study Area																	
Primary Roads	0.12	0.00	6.29	603.5	0.2	28106.4	10.5							0.03	0.017	19.0	0.31
Secondary Roads	0.14	0.00	8.10	749.5	0.3	31730.3	11.8							0.04	0.021	23.4	0.39
Truck Trails	0.36	0.00	10.49	767.5	0.3	29169.1	10.9							0.16	0.088	36.3	0.60
Pipelines	0.05	0.00	2.63	265.9	0.1	2550.3	1.0							0.02		10.2	0.17
Railway Lines	0.02	0.00	1.46	124.6	0.0	1337.0	0.5							0.01		4.1	0.07
Cutlines	1.23	0.00	20.19	2664.4	1.0	0.0	0.0							0.59		127.7	2.11
Communities				19.6	0.0	28.0	0.0									0.0	0.00
Wellsites				199.6	0.1	4246.0	1.6									4.4	0.07
Clearings				7622.2	2.8	5181.4	1.9									417.9	6.91
Existing Total	**0.62[7]**	**0.00[7]**	**17.13[7]**	**13017**	**4.9**	**102348**	**38**	**116028**	**43**	**185**	**627.2**	**0.0**	**29074**	**0.84[8]**	**0.126[9]**	**643.12**	**10.6**
Jedney RMZ																	
Primary Roads	0.10	0.00	2.31	327.0	0.2	15323.7	9.6							0.03	0.016	10.4	
Secondary Roads	0.12	0.00	2.66	357.8	0.2	17119.7	10.7							0.03	0.017	11.4	
Truck Trails	0.33	0.00	4.64	426.5	0.3	17557.5	10.9							0.16	0.084	23.2	
Pipelines	0.04	0.00	1.33	140.0	0.1	1889.8	1.2							0.02		5.9	
Railway Lines	0.02	0.00	1.24	58.4	0.0	567.6	0.4							0.01		1.8	
Cutlines	1.23	0.00	7.29	1624.7	1.0	0.0	0.0							0.60		81.6	
Communities				0.0	0.0	3.4	0.0									0.0	
Wellsites				154.4	0.1	3526.6	2.2									3.4	
Clearings				1902.4	1.2	1962.1	1.2									110.4	
Existing Total	**0.55[7]**	**0.00[7]**	**4.95[7]**	**4991**	**3.1**	**57950**	**36**	**75844**	**47**	**103**	**736.3**	**0.0**	**28572**	**0.83[8]**	**0.116[9]**	**248.13**	
Agriculture Settlement Area RMZ																	
Primary Roads	0.16	0.00	6.29	271.7	0.3	12156.2	13.0							0.05	0.021	8.7	
Secondary Roads	0.17	0.00	2.95	327.8	0.3	12142.3	12.9							0.06	0.027	10.8	
Truck Trails	0.41	0.00	4.22	308.3	0.3	10618.0	11.3							0.17	0.102	12.5	
Pipelines	0.06	0.00	2.63	113.2	0.1	646.8	0.7							0.03		3.9	
Railway Lines	0.03	0.00	1.46	53.9	0.1	620.9	0.7							0.02		2.2	
Cutlines	1.30	0.00	20.19	959.0	1.0	0.0	0.0							0.61		43.6	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				42.6	0.0	701.8	0.7									1.0	
Clearings				5695.3	6.1	3216.5	3.4									306.1	
Existing Total	**0.74[7]**	**0.00[7]**	**6.29[7]**	**7772**	**8.3**	**40103**	**43**	**32457**	**35**	**106**	**306.2**	**0.0**	**6168**	**0.89[8]**	**0.150[9]**	**388.82**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.
4 Percent (%) of specified area, excluding lakes.
5 Includes linear features within 100 m of a stream.
6 Includes all cleared areas within 15 m of a waterbody.
7 Total corridor density includes roads and truck trails.
8 Total stream crossings include roads, truck trails, pipelines, and cutlines.
9 Total valley roads include roads and truck trails.
10 Percent of total riparian area.

1970 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²) min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	Total ha	(% of area)[4]	No	Average Size (ha)	Range (ha) min	max	(#/km)	(km/km²)	(ha)	(% of area)[4]
Grazing Reserve 1 RMZ																	
Primary Roads	0.08	0.00	1.25	0.0	0.0	283.3	3.2							0.00	0.000	0.0	
Secondary Roads	0.05	0.00	1.19	9.9	0.1	519.5	5.8							0.00	0.000	0.0	
Truck Trails	0.16	0.00	2.78	10.2	0.1	491.7	5.5							0.04	0.021	0.2	
Pipelines	0.03	0.00	1.10	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.10	0.00	1.12	12.3	0.1	148.5	1.7							0.01		0.1	
Cutlines	0.86	0.00	3.97	53.7	0.6	0.0	0.0							0.33		1.7	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.29[7]**	**0.00[7]**	**3.91[7]**	**86**	**1.0**	**1443**	**16**	**6608**	**74**	**2**	**3304.2**	**34.7**	**6574**	**0.38[8]**	**0.021[9]**	**1.96**	
Alaska Highway Corridor RMZ																	
Primary Roads	0.08	0.00	2.88	4.8	0.1	343.3	7.4							0.00	0.003	0.0	
Secondary Roads	0.47	0.00	8.10	54.0	1.2	1948.9	41.7							0.17	0.073	1.2	
Truck Trails	0.70	0.00	10.49	22.5	0.5	501.9	10.7							0.19	0.108	0.4	
Pipelines	0.12	0.00	2.63	12.6	0.3	13.7	0.3							0.04		0.3	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.64	0.00	6.42	27.0	0.6	0.0	0.0							0.28		0.8	
Communities				19.6	0.4	24.6	0.5									0.0	
Wellsites				2.7	0.1	17.6	0.4									0.0	
Clearings				24.6	0.5	2.8	0.1									1.4	
Existing Total	**1.25[7]**	**0.00[7]**	**17.13[7]**	**168**	**3.6**	**2853**	**61**	**1118**	**24**	**26**	**43.0**	**0.0**	**233**	**0.66[8]**	**0.185[9]**	**4.21**	
Beatton River Watershed																	
Primary Roads	0.05	0.00	1.76	25.3	0.1	1507.0	4.6							0.01	0.003	0.4	0.0
Secondary Roads	0.08	0.00	2.74	37.8	0.1	2159.8	6.6							0.02	0.008	1.3	0.2
Truck Trails	0.27	0.00	10.49	67.9	0.2	3657.4	11.2							0.13	0.074	4.2	0.5
Pipelines	0.02	0.00	1.29	13.3	0.0	267.4	0.8							0.01		0.4	0.1
Railway Lines	0.02	0.00	1.20	14.5	0.0	104.1	0.3							0.00		0.3	0.0
Cutlines	0.95	0.00	7.29	269.6	0.8	0.0	0.0							0.44		11.5	1.5
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				10.6	0.0	144.9	0.4									0.0	0.0
Clearings				51.7	0.2	133.9	0.4									6.8	0.9
Existing Total	**0.40[7]**	**0.00[7]**	**10.49[7]**	**491**	**1.5**	**7975**	**24**	**19741**	**60**	**25**	**789.6**	**0.0**	**9525**	**0.59[8]**	**0.086[9]**	**24.80**	**3.2**

1 Area occupied by disturbance feature (roads and utility corridors 20 m wide, cutlines and truck trails 8 m wide; other features as calculated)
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines
4 Percent (%) of specified area, excluding lakes
5 Includes linear features within 100 m of a stream
6 Includes all cleared areas within 15 m of a waterbody
7 Total corridor density includes roads and truck trails
8 Total stream crossings include roads, truck trails, pipelines, and cutlines
9 Total valley roads include roads and truck trails
10 Percent of total riparian area

1970 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Nig Creek Watershed																	
Primary Roads	0.15	0.00	2.05	128.6	0.3	5821.9	13.6							0.04	0.020	3.3	0.3
Secondary Roads	0.12	0.00	2.15	104.4	0.2	3829.0	9.0							0.05	0.025	4.4	0.4
Truck Trails	0.29	0.00	4.64	98.4	0.2	3848.8	9.0							0.12	0.059	3.5	0.3
Pipelines	0.02	0.00	1.29	10.7	0.0	238.6	0.6							0.00		0.3	0.0
Railway Lines	0.05	0.00	1.24	41.0	0.1	678.0	1.6							0.02		1.4	0.1
Cutlines	1.58	0.00	5.60	533.6	1.3	0.0	0.0							0.71		21.7	2.0
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				23.4	0.1	501.8	1.2									0.4	0.0
Clearings				1661.5	3.9	1573.9	3.7									56.1	5.1
Existing Total	**0.56**[7]	**0.00**[7]	**4.64**[7]	**2602**	**6.1**	**16492**	**39**	**18021**	**42**	**40**	**450.5**	**0.0**	**5964**	**0.93**[8]	**0.103**[9]	**91.01**	**8.2**
Aitken Creek Watershed																	
Primary Roads	0.16	0.00	2.31	259.0	0.3	11901.1	14.7							0.05	0.028	8.9	0.5
Secondary Roads	0.17	0.00	2.13	267.3	0.3	11163.4	13.8							0.05	0.024	8.1	0.5
Truck Trails	0.41	0.00	3.93	270.5	0.3	9658.6	11.9							0.19	0.104	12.8	0.7
Pipelines	0.08	0.00	2.34	141.1	0.2	781.1	1.0							0.03		4.8	0.3
Railway Lines	0.02	0.00	1.12	23.1	0.0	102.6	0.1							0.00		0.6	0.0
Cutlines	1.29	0.00	6.82	827.3	1.0	0.0	0.0							0.63		42.8	2.4
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				85.5	0.1	1432.9	1.8									2.1	0.1
Clearings				2417.6	3.0	1308.2	1.6									172.9	9.7
Existing Total	**0.74**[7]	**0.00**[7]	**4.77**[7]	**4291**	**5.3**	**36348**	**45**	**28957**	**36**	**84**	**344.7**	**0.0**	**6878**	**0.95**[8]	**0.156**[9]	**252.83**	**14.2**
Umbach Creek Watershed																	
Primary Roads	0.18	0.00	6.29	52.3	0.2	1885.1	6.9							0.04	0.013	3.0	0.5
Secondary Roads	0.10	0.00	1.98	52.3	0.2	2343.4	8.6							0.01	0.006	0.6	0.1
Truck Trails	0.28	0.00	2.69	60.5	0.2	2561.5	9.4							0.13	0.061	2.5	0.4
Pipelines	0.03	0.00	2.30	0.1	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.08	0.00	1.46	46.0	0.2	452.3	1.7							0.05		1.9	0.3
Cutlines	1.38	0.00	20.19	290.8	1.1	0.0	0.0							0.73		14.6	2.5
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				6.5	0.0	50.3	0.2									0.0	0.0
Clearings				986.6	3.6	610.0	2.2									60.4	10.2
Existing Total	**0.57**[7]	**0.00**[7]	**6.29**[7]	**1497**	**5.5**	**7903**	**29**	**14375**	**52**	**20**	**718.8**	**0.0**	**12970**	**0.94**[8]	**0.080**[9]	**83.06**	**14.1**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines
4 Percent (%) of specified area, excluding lakes
5 Includes linear features within 100 m of a stream
6 Includes all cleared areas within 15 m of a waterbody
7 Total corridor density includes roads and truck trails
8 Total stream crossings include roads, truck trails, pipelines, and cutlines
9 Total valley roads include roads and truck trails
10 Percent of total riparian area

1970 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Creek Watershed																	
Primary Roads	0.09	0.00	2.88	130.6	0.2	6577.8	8.0							0.02	0.012	3.4	0.2
Secondary Roads	0.19	0.00	8.10	272.9	0.3	11781.2	14.4							0.04	0.025	8.6	0.5
Truck Trails	0.43	0.00	10.49	261.5	0.3	9219.5	11.3							0.18	0.103	13.2	0.7
Pipelines	0.06	0.00	2.63	90.9	0.1	1191.6	1.5							0.03		4.4	0.2
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	1.12	0.00	7.29	728.2	0.9	0.0	0.0							0.52		36.6	2.1
Communities				18.9	0.0	27.5	0.0									0.0	0.0
Wellsites				72.3	0.1	2115.3	2.6									1.9	0.1
Clearings				2490.6	3.0	1493.3	1.8									119.2	6.7
Existing Total	**0.70[7]**	**0.00[7]**	**17.13[7]**	**4066**	**5.0**	**32406**	**40**	**34312**	**42**	**67**	**512.1**	**0.0**	**11307**	**0.77[8]**	**0.140[9]**	**187.41**	**10.5**
Misc Lower Beatton River Watershed																	
Primary Roads	0.35	0.00	1.46	6.6	0.7	299.3	31.8							0.14	0.046	0.1	1.9
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Truck Trails	0.13	0.00	1.20	1.0	0.1	56.5	6.0							0.00	0.000	0.0	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	1.33	0.00	3.28	8.8	0.9	0.0	0.0							0.77		0.4	5.3
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				7.2	0.8	62.0	6.6									2.2	28.7
Existing Total	**0.48[7]**	**0.00[7]**	**1.96[7]**	**24**	**2.5**	**418**	**44**	**371**	**39**	**4**	**92.7**	**0.0**	**226**	**0.84[8]**	**0.046[9]**	**2.71**	**36.9**
Lower Peace River Watershed																	
Primary Roads	0.08	0.00	1.46	0.3	0.0	85.2	7.9							0.00	0.000	0.0	0.0
Secondary Roads	0.52	0.00	2.67	10.5	1.0	363.8	33.9							0.32	0.116	0.4	3.1
Truck Trails	0.59	0.00	4.22	5.5	0.5	145.4	13.6							0.26	0.096	0.1	1.0
Pipelines	0.24	0.00	2.63	8.7	0.8	71.5	6.7							0.16		0.3	2.4
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.68	0.00	6.42	4.4	0.4	0.0	0.0							0.00		0.1	0.7
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				5.1	0.5	0.0	0.0									0.4	3.1
Existing Total	**1.19[7]**	**0.00[7]**	**4.74[7]**	**35**	**3.2**	**666**	**62**	**245**	**23**	**7**	**35.0**	**0.6**	**160**	**0.63[8]**	**0.212[9]**	**1.20**	**10.3**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines

4 Percent (%) of specified area, excluding lakes

5 Includes linear features within 100 m of a stream

6 Includes all cleared areas within 15 m of a waterbody

7 Total corridor density includes roads and truck trails

8 Total stream crossings include roads, truck trails, pipelines, and cutlines

9 Total valley roads include roads and truck trails

10 Percent of total riparian area

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²) min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	Total ha	(% of area)[4]	No	Average Size (ha)	Range (ha) min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Study Area																	
Primary Roads	0.34	0.00	94.95	944.8	0.4	36400.2	13.6							0.05	0.026	27.0	0.4
Secondary Roads	0.27	0.00	8.10	1398.8	0.5	44642.6	16.7							0.08	0.040	42.7	0.7
Truck Trails	1.00	0.00	10.68	2088.0	0.8	48360.6	18.1							0.37	0.221	87.8	1.5
Pipelines	0.09	0.00	2.98	453.1	0.2	1887.2	0.7							0.04		18.9	0.3
Railway Lines	0.02	0.00	1.79	126.5	0.0	974.7	0.4							0.01		4.1	0.1
Cutlines	2.54	0.00	21.53	5420.0	2.0	0.0	0.0							1.19		265.3	4.4
Communities				19.5	0.0	14.8	0.0									0.0	0.0
Wellsites				880.4	0.3	14679.0	5.5									16.5	0.3
Clearings				23063.0	8.6	8928.3	3.3									973.8	16.1
Existing Total	**1.61[7]**	**0.00[7]**	**94.95[7]**	**34394**	**12.8**	**155888**	**58**	**40618**	**15**	**352**	**115.4**	**0.0**	**3589**	**1.68[8]**	**0.287[9]**	**1436.16**	**23.7**
Jedney RMZ																	
Primary Roads	0.16	0.00	10.84	453.9	0.3	18006.2	11.2							0.04	0.021	12.9	
Secondary Roads	0.24	0.00	3.60	723.1	0.5	25924.8	16.2							0.07	0.033	22.7	
Truck Trails	0.87	0.00	10.68	1080.5	0.7	29269.4	18.3							0.34	0.195	51.0	
Pipelines	0.08	0.00	1.90	236.5	0.1	1491.3	0.9							0.03		9.9	
Railway Lines	0.02	0.00	1.79	60.5	0.0	451.9	0.3							0.01		1.8	
Cutlines	2.41	0.00	8.81	3107.5	1.9	0.0	0.0							1.13		160.7	
Communities				0.0	0.0	3.4	0.0									0.0	
Wellsites				512.1	0.3	10925.7	6.8									9.8	
Clearings				10348.4	6.5	5334.2	3.3									416.5	
Existing Total	**1.26[7]**	**0.00[7]**	**10.84[7]**	**16523**	**10.3**	**91407**	**57**	**28269**	**18**	**236**	**119.8**	**0.0**	**3220**	**1.57[8]**	**0.250[9]**	**685.32**	
Agriculture Settlement Area RMZ																	
Primary Roads	0.26	0.00	6.29	427.4	0.5	15598.6	16.6							0.08	0.037	13.3	
Secondary Roads	0.31	0.00	3.26	593.7	0.6	17513.4	18.7							0.09	0.052	18.3	
Truck Trails	1.17	0.00	7.56	881.8	0.9	16861.9	18.0							0.43	0.273	34.1	
Pipelines	0.10	0.00	2.98	185.2	0.2	289.8	0.3							0.05		7.6	
Railway Lines	0.03	0.00	1.46	53.7	0.1	391.1	0.4							0.02		2.2	
Cutlines	2.87	0.00	21.53	2101.7	2.2	0.0	0.0							1.34		97.9	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				345.7	0.4	3395.4	3.6									6.3	
Clearings				10968.8	11.7	2975.0	3.2									477.6	
Existing Total	**1.74[7]**	**0.00[7]**	**9.28[7]**	**15558**	**16.6**	**57025**	**61**	**10345**	**11**	**131**	**79.0**	**0.0**	**1508**	**1.91[8]**	**0.362[9]**	**657.32**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.
4 Percent (%) of specified area, excluding lakes.
5 Includes linear features within 100 m of a stream.
6 Includes all cleared areas within 15 m of a waterbody.
7 Total corridor density includes roads and truck trails.
8 Total stream crossings include roads, truck trails, pipelines, and cutlines.
9 Total valley roads include roads and truck trails.
10 Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Grazing Reserve 1 RMZ																	
Primary Roads	0.09	0.00	1.25	0.6	0.0	335.6	3.8							0.00	0.000	0.0	
Secondary Roads	0.08	0.00	1.79	13.9	0.2	637.5	7.2							0.01	0.004	0.2	
Truck Trails	0.85	0.00	4.28	64.4	0.7	1885.5	21.2							0.18	0.087	1.0	
Pipelines	0.03	0.00	1.10	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.10	0.00	1.12	12.3	0.1	131.7	1.5							0.01		0.1	
Cutlines	2.05	0.00	5.95	136.3	1.5	0.0	0.0							0.86		4.4	
Communities				0.0	0.0	0.0	0.0									0.0	
Wellsites				10.7	0.1	300.9	3.4									0.4	
Clearings				1118.5	12.6	608.1	6.8									40.7	
Existing Total	**1.02[7]**	**0.00[7]**	**4.28[7]**	**1357**	**15.3**	**3899**	**44**	**1993**	**22**	**15**	**132.9**	**0.1**	**847**	**1.04[8]**	**0.091[9]**	**46.78**	
Alaska Highway Corridor RMZ																	
Primary Roads	3.70	0.00	94.95	62.8	1.3	2459.7	52.7							0.35	0.009	0.8	
Secondary Roads	0.63	0.00	8.10	68.1	1.5	567.0	12.1							0.23	0.126	1.5	
Truck Trails	1.56	0.00	10.49	61.3	1.3	343.9	7.4							0.62	0.326	1.8	
Pipelines	0.24	0.00	2.63	31.4	0.7	106.1	2.3							0.24		1.3	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	1.88	0.00	9.25	74.5	1.6	0.0	0.0							0.90		2.2	
Communities				19.5	0.4	11.4	0.2									0.0	
Wellsites				11.8	0.3	57.0	1.2									0.0	
Clearings				627.3	13.4	11.1	0.2									39.0	
Existing Total	**5.89[7]**	**0.00[7]**	**94.95[7]**	**957**	**20.5**	**3556**	**76**	**12**	**0**	**5**	**2.3**	**0.0**	**4**	**2.29[8]**	**0.461[9]**	**46.72**	
Beatton River Watershed																	
Primary Roads	0.59	0.00	94.95	88.8	0.3	3391.8	10.3							0.03	0.012	1.6	0.2
Secondary Roads	0.24	0.00	3.60	122.5	0.4	4676.9	14.3							0.06	0.024	3.8	0.5
Truck Trails	0.87	0.00	10.68	205.4	0.6	6297.6	19.2							0.31	0.181	10.4	1.3
Pipelines	0.05	0.00	2.40	16.6	0.1	113.5	0.3							0.01		0.5	0.1
Railway Lines	0.02	0.00	1.79	16.7	0.1	22.4	0.1							0.00		0.3	0.0
Cutlines	2.07	0.00	9.53	584.8	1.8	0.0	0.0							0.97		26.8	3.5
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				69.8	0.2	1451.8	4.4									0.4	0.1
Clearings				1759.3	5.4	1500.1	4.6									89.9	11.7
Existing Total	**1.70[7]**	**0.00[7]**	**94.95[7]**	**2864**	**8.7**	**17454**	**53**	**7128**	**22**	**65**	**109.7**	**0.0**	**1772**	**1.35[8]**	**0.217[9]**	**133.74**	**17.3**

[1] Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

[2] Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

[3] Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

[4] Percent (%) of specified area, excluding lakes.

[5] Includes linear features within 100 m of a stream.

[6] Includes all cleared areas within 15 m of a waterbody.

[7] Total corridor density includes roads and truck trails.

[8] Total stream crossings include roads, truck trails, pipelines, and cutlines.

[9] Total valley roads include roads and truck trails.

[10] Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No.	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Nig Creek Watershed																	
Primary Roads	0.21	0.00	2.46	173.1	0.4	7248.4	17.0							0.06	0.026	4.5	0.4
Secondary Roads	0.21	0.00	2.35	186.3	0.4	6630.5	15.5							0.09	0.037	8.1	0.7
Truck Trails	0.74	0.00	5.18	251.8	0.6	6671.9	15.6							0.29	0.148	9.3	0.8
Pipelines	0.03	0.00	1.29	13.4	0.0	186.9	0.4							0.01		0.4	0.0
Railway Lines	0.05	0.00	1.25	40.9	0.1	555.5	1.3							0.02		1.3	0.1
Cutlines	3.02	0.00	7.89	1005.4	2.4	0.0	0.0							1.46		47.3	4.3
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				80.9	0.2	2146.6	5.0									2.3	0.2
Clearings				3002.0	7.0	2024.7	4.7									100.9	9.1
Existing Total	**1.17[7]**	**0.00[7]**	**5.18[7]**	**4754**	**11.1**	**25465**	**60**	**7061**	**17**	**71**	**99.4**	**0.0**	**1208**	**1.87[8]**	**0.210[9]**	**174.09**	**15.7**
Aitken Creek Watershed																	
Primary Roads	0.21	0.00	2.31	339.0	0.4	12933.0	16.0							0.07	0.039	11.2	0.6
Secondary Roads	0.32	0.00	2.88	491.4	0.6	15053.7	18.6							0.09	0.048	13.9	0.8
Truck Trails	1.09	0.00	7.56	706.0	0.9	14449.0	17.9							0.43	0.266	30.8	1.7
Pipelines	0.13	0.00	2.98	207.4	0.3	596.0	0.7							0.05		7.7	0.4
Railway Lines	0.02	0.00	1.12	23.0	0.0	92.2	0.1							0.00		0.6	0.0
Cutlines	2.60	0.00	8.39	1651.9	2.0	0.0	0.0							1.20		84.0	4.7
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				355.5	0.4	5078.0	6.3									7.2	0.4
Clearings				7292.3	9.0	1903.1	2.4									314.7	17.7
Existing Total	**1.62[7]**	**0.00[7]**	**7.63[7]**	**11066**	**13.7**	**50105**	**62**	**9390**	**12**	**125**	**75.1**	**0.0**	**1256**	**1.77[8]**	**0.353[9]**	**470.10**	**26.4**
Umbach Creek Watershed																	
Primary Roads	0.21	0.00	6.29	63.1	0.2	2209.9	8.1							0.04	0.014	3.1	0.5
Secondary Roads	0.17	0.00	3.26	81.7	0.3	2850.6	10.4							0.03	0.018	1.7	0.3
Truck Trails	0.93	0.00	7.08	205.2	0.7	5640.7	20.6							0.31	0.164	6.5	1.1
Pipelines	0.04	0.00	2.30	6.5	0.0	0.0	0.0							0.01		0.4	0.1
Railway Lines	0.08	0.00	1.46	45.9	0.2	304.6	1.1							0.05		1.9	0.3
Cutlines	2.62	0.00	21.53	550.9	2.0	0.0	0.0							1.22		25.2	4.3
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				53.3	0.2	864.6	3.2									1.0	0.2
Clearings				3105.0	11.3	1557.1	5.7									131.5	22.3
Existing Total	**1.30[7]**	**0.00[7]**	**8.28[7]**	**4112**	**15.0**	**13427**	**49**	**5289**	**19**	**38**	**139.2**	**0.0**	**1508**	**1.59[8]**	**0.196[9]**	**171.42**	**29.1**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Blueberry Creek Watershed																	
Primary Roads	0.49	0.00	37.80	243.5	0.3	9791.8	12.0							0.04	0.021	6.2	0.3
Secondary Roads	0.33	0.00	8.10	489.4	0.6	15085.3	18.4							0.08	0.046	14.5	0.8
Truck Trails	1.12	0.00	10.49	692.5	0.8	14937.7	18.2							0.40	0.253	30.5	1.7
Pipelines	0.13	0.00	2.63	199.5	0.2	987.0	1.2							0.06		9.6	0.5
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	2.50	0.00	9.24	1576.4	1.9	0.0	0.0							1.13		79.8	4.5
Communities				18.8	0.0	14.8	0.0									0.0	0.0
Wellsites				312.7	0.4	5039.4	6.2									5.3	0.3
Clearings				7741.8	9.5	1907.1	2.3									327.3	18.4
Existing Total	**1.94[7]**	**0.00[7]**	**37.80[7]**	**11275**	**13.8**	**47763**	**58**	**11692**	**14**	**89**	**131.4**	**0.0**	**2716**	**1.64[8]**	**0.320[9]**	**473.26**	**26.6**
Misc Lower Beatton River Watershed																	
Primary Roads	0.39	0.00	2.33	6.6	0.7	244.1	25.9							0.14	0.046	0.1	1.9
Secondary Roads	0.25	0.00	2.42	7.2	0.8	149.7	15.9							0.00	0.039	0.0	0.0
Truck Trails	1.26	0.00	3.30	12.4	1.3	236.1	25.1							0.14	0.056	0.1	1.2
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	4.25	1.44	7.10	32.7	3.5	0.0	0.0							2.81		1.5	19.4
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				3.4	0.4	15.9	1.7									0.1	1.5
Clearings				94.3	10.0	26.4	2.8									5.7	75.8
Existing Total	**1.90[7]**	**0.00[7]**	**4.08[7]**	**157**	**16.6**	**672**	**71**	**40**	**4**	**2**	**19.8**	**7.6**	**32**	**3.02[8]**	**0.142[9]**	**7.55**	**99.9**
Lower Peace River Watershed																	
Primary Roads	2.57	0.00	22.56	19.4	1.8	459.4	42.8							0.48	0.000	0.3	2.5
Secondary Roads	0.86	0.00	5.69	16.2	1.5	195.8	18.3							0.48	0.275	0.6	5.1
Truck Trails	1.40	0.00	5.04	12.3	1.1	117.2	10.9							0.26	0.251	0.2	1.5
Pipelines	0.26	0.00	2.63	8.7	0.8	3.8	0.4							0.16		0.3	2.4
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	1.93	0.00	9.25	15.0	1.4	0.0	0.0							0.58		0.7	5.9
Communities				0.0	0.0	0.0	0.0									0.0	0.0
Wellsites				3.6	0.3	82.5	7.7									0.0	0.0
Clearings				63.5	5.9	9.8	0.9									3.8	32.6
Existing Total	**4.83[7]**	**0.31[7]**	**23.22[7]**	**139**	**12.9**	**869**	**81**	**20**	**2**	**2**	**9.8**	**0.6**	**19**	**1.80[8]**	**0.526[9]**	**5.82**	**50.0**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.
4 Percent (%) of specified area, excluding lakes.
5 Includes linear features within 100 m of a stream.
6 Includes all cleared areas within 15 m of a waterbody.
7 Total corridor density includes roads and truck trails.
8 Total stream crossings include roads, truck trails, pipelines, and cutlines.
9 Total valley roads include roads and truck trails.
10 Percent of total riparian area.

Cumulative Effects Assessment and Management
for
Northeast British Columbia

Volume 2
Cumulative Effects Indicators, Thresholds and Case Studies

Appendix 3
Sukunka Cumulative Effects Case Study

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February, 2003

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GLOSSARY

Access corridor – a linear feature created by humans (road, trail, pipeline, powerline, railway line, cutline) that may be used by pedestrians, vehicles, hunters, anglers, or animal predators.

ALCES – 'A Landscape Cumulative Effects Simulator' computer model used to forecast changes in landscape patterns and wildlife habitat. This simulator integrates four submodels (habitat availability, population, land use, and natural disturbance) and considers all land use activities likely to occur in the region. It includes both aquatic and terrestrial indicators and is able to incorporate random events such as fire.

Barrier – a barrier is present when it is not possible for animals to move across a corridor, and the habitat on either side of the corridor becomes isolated (e.g., a busy highway is a barrier for small ground-dwelling insects)

Biodiversity – the diversity of plants, animals, and other living organisms in all their forms and levels of organization (BCF and BCE 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Biogeoclimatic zone – a geographic area having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macro-climate (BCF and BCE 1995a).

Cautionary threshold – a threshold established to indicate that additional or more intensive monitoring is required to provide sufficient local data to confirm scientific predictions of both target and critical thresholds.

CEAM – Cumulative Effects Assessment and Management framework consisting of an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley; windrow, aeolian ridge) or as the result of human disturbance (e.g., roads, cutlines).

Critical threshold – a science-based target reflecting the continuous maximum amount of stress that a sensitive ecosystem or species can support without sustaining long-term harm. This may incorporate economic and social values to determine the acceptable magnitude of change, risk of long-term damage, or level of protection required.

Cumulative effects – changes to the environment caused by collective past, present, and future human actions; most result from the combined effects of simple, routine activities and projects.

DC – Disturbance Coefficient; an index assigned to each feature or activity type that rates the degree to which the disturbance zone of influence remains effectively useable by the species. Ratings are on a scale of 0 to 1 and are used to calculate habitat effectiveness.

Density-dependent – factors that affect population growth and parameters in relation to as animal abundance. These depress population growth as animal abundance increases, and increase growth as animal abundance decreases. Examples include food availability and quality. Predation may be density-dependent or –independent.

Density-independent – factors that affect population growth and parameters regardless of animal abundance. Examples include natural environmental disturbances such as fire, floods, or severe weather. Predation may be density-dependent or –independent.

Disturbance – a natural or human action that affects physical, chemical, or biological conditions.

Disturbance feature – a corridor or patch created by natural random events (e.g., burn or flood) or human action (e.g., cutblock, facility, community, road).

Disturbance trajectory – the calculated or predicted rate of natural or human disturbance.

Drainage – a subset of a watershed, generally less than 1,000 km^2 in size.

Early seral – forest that are younger than 40 years old (BCF and MELP 1999b).

Ecological resilience – the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996).

Ecological sink – an area with degraded habitat that has lower survival (or higher mortality) rates, causing local population declines. Although individual animals may continue to use this area, it creates a net loss to the population that may not be detectable for several generations.

Edge area – the area bordering patches and corridors where abiotic conditions (e.g., moisture, light, temperature, wind regimes) and biotic conditions (e.g., predation, mortality, competition, vegetation diversity and structure, species diversity and abundance) may be altered. Examples include the intersection between a cutblock and forest or a trail and native grassland.

Filter or porous barrier – a type of corridor across which some movement occurs but the rate of movement is less than through intact habitat (e.g., a busy highway is a porous barrier for large mobile wildlife like deer [*Odocoileus* spp.]).

Fragmentation – the process of losing habitat continuity through temporary or permanent conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). Three general effects result from habitat fragmentation: (1) original habitat is lost, (2) remaining habitat patches decrease in size, and, (3) patches become increasingly isolated from one another.

Habitat – the environment in which an organism or biological population lives or grows.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest regrowth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production; introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat availability – the amount of usable habitat accessible to a particular species.

Habitat capability – the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999).

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness for that species.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and regrowth is not allowed to occur (e.g., construction of a city, highway or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Habitat suitability – the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (RIC 1999).

Habitat unit – a defined terrestrial or aquatic unit with consistent abiotic and biotic conditions.

Hazard level – the risk of an adverse cumulative hydrological effect defined by the British Columbia Interior Watershed Assessment Procedure (IWAP; BCF and BCE 1995b; BCF 1999).

Human activity – all forms of human actions including land conversion and disturbance, damming, water withdrawal, pedestrian, vehicle and aircraft movements, harassment, harvest, and contaminant input.

Index or metric – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator – a surrogate measure used to represent or monitor the condition of an abiotic or biotic resource. May be a representative species, an outcome, or an input.

Interior area – also referred to as core area in this report. Interior areas are those beyond the influence of edge effects.

IWAP – Interior Watershed Assessment Procedure; a method developed by the provincial government to help forest managers understand the type and extent of current water-related problems in a watershed, and to recognize the implications of proposed activity in that watershed (BCF 1999).

Juvenile – an individual age 1 or older that has not reached maturity.

Landscape – an area of tens to hundreds of square kilometres that includes one dominant background ecosystem. Northeast British Columbia consists of a number of landscape types including the forest landscape, the agricultural landscape, and the alpine/subalpine landscape.

Local population – a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Lowest observed effect level – concept from the field of ecotoxicology that represents the lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms compared to the controls. Also called lowest observed adverse effect level (LOAEL). This concept is also applicable to behavioural, physiological, and population response.

LU – Landscape Unit; an area of land and water used for long-term planning of resource management activities according to the *Forest Practices Code of British Columbia Act*. It may be used for designed strategies and patterns for landscape level biodiversity and for managing other forest resources (BCF and MELP 1999b).

LRMP – Land Resource Management Plan; a plan approved by the provincial government that establishes direction for land use and specifies broad resource management objectives and strategies.

Matrix – the dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Mature growth/mature seral – forests greater than a specified age (generally >80 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Metapopulation – a population of populations. This represents an abstraction of the population concept to a higher level. Metapopulations generally consist of a group of interacting but spatially discrete or isolated populations, subpopulations, or stocks. These subunits are linked by drainage networks but movement between subunits is infrequent and typically takes place across unsuitable habitat or over great distances (Hanski and Gilpin 1991; Dunham and Rieman 1999). An example of a fish metapopulation is a group of isolated headwaters populations found in the same watershed.

MSRM – British Columbia Ministry of Sustainable Resource Management

Natural disturbance type – an area characterized by a natural disturbance regime. The provincial government has established five natural disturbance types for managing biological diversity according to the *Forest Practices Code of British Columbia Act* (BCF and BCE 1995a; BCF and MELP 1999b).

OGC – British Columbia Oil and Gas Commission.

Old growth/old seral – forests greater than a specified age (generally >100 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches can occur naturally (e.g., sloughs, burns) or as the result of human disturbance (e.g., farmyards, well sites, clearcuts).

Population – a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population limiting factors – processes quantifiably affect the population rate-of-increase. Responsible for inducing year-to-year changes in animal abundance (Messier 1991).

Population regulating factors – density-dependent processes that ultimately keep populations within normal density ranges. These are a subset of limiting factors and predictably depress population growth as animal abundance increases (Messier 1991).

Reach – a defined watercourse channel section, tens to thousands of meters in length, with relatively consistent channel morphology, hydrology, and water chemistry.

Regional – an area more than hundreds of square kilometres that incorporates several landscapes.

Riparian – the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995c; BCF and MELP 1999b).

Riparian clearings – cleared areas within 15 m of a waterbody, including linear corridors, communities and residences, industrial and commercial facilities, cutblocks, and agricultural fields.

Riparian roads – roads and trails within 100 m of a waterbody.

RMZ – Resource Management Zone; defined subdivisions of an approved LRMP that have unique sets of resource values, objectives to maintain or enhance those values, and a number of strategies to be implemented to achieve those objectives. These provide geographically-focused, strategic direction (Fort St. John LRMP 1997).

Seral stage – the stages of natural ecological succession of a plant community, for example from young through mature to old stage (BCF and BCE 1995a).

Stream crossing – a road, trail, pipeline, powerline, railway line, or cutline crossing of a watercourse.

Subpopulation – a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Subwatershed – a subset of a watershed, generally less than 1,000 km^2 in size.

Target threshold – a politically-defined goal reflecting the optimum amount of stress on the system. This threshold is more protective than the critical threshold to provide a margin of safety. A target threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

Threshold – a point at which a resource changes to an unacceptable condition, with acceptability defined either from an ecological or social perspective.

Viable population – a self-sustaining population with a high probability of survival despite the foreseeable effects of demographic, environmental, and genetic stochasticity and of natural catastrophes (BCF and BCE 1995a).

Waterbody – a specific aquatic basins or channel (lake, pond, wetland, river, or stream).

Watercourse – a specific flowing channel (river or stream).

Watershed – a large drainage area, generally 1,000 to 10,000 km^2 in size, which flows directly into a large river such as the Peace River.

WHA – Wildlife Habitat Area contain critical habitat elements for one or more species of Identified Wildlife. These areas are mapped and approved by the Chief Forester and WLAP according to the *Forest Practices Code of British Columbia Act.*

WLAP – British Columbia Ministry of Water, Land and Air Protection.

ZOI – Zone of Influence; the distance to which a species is affected by an activity or disturbance.

1. INTRODUCTION

As part of the British Columbia Oil and Gas Commission's (OGC) initiative to address environmental effects associated with oil and gas development, an environmental fund has been established for research projects over a five-year period. Cumulative effects was one of three research envelopes for which funding was provided.

Salmo Consulting Inc. (Salmo), Diversified Environmental Services (Diversified), Axys Environmental Consulting Ltd. (Axys), and GAIA Consultants Inc. (GAIA) received funding under the Cumulative Effects Research envelope to conduct three separate but integrated studies. In combination, these studies will provide an over-arching strategy and approach for identifying, scoping, assessing and managing cumulative effects in northeast British Columbia (hereafter referred to as cumulative effects assessment and management, or CEAM). The three components are:

- Development of an overall CEAM Framework.
- Detailed assessment of cumulative effects and thresholds in two Case Studies.
- Development of a Decision Support system.

All components contribute to the development of a framework to aid the OGC in ensuring that cumulative effects are consistently addressed and managed as part of their ongoing project approval process.

The Cumulative Effects Indicators, Thresholds, and Case Studies (Thresholds and Case Studies) component, conducted by Salmo, Diversified, GAIA, and Forem Technologies Ltd. (Forem), is intended to help test and develop approaches for assessing cumulative effects, determining impact significance using actual data from two representative areas in northeastern British Columbia (Blueberry and Sukunka).

This report provides the case study for the Sukunka representative area. It is divided into three main sections:

Section 2. Regional Setting

- Summarizes information on the biophysical and administrative setting relevant to environmental planning and management in the Sukunka Case Study area.

Section 3. Development and Resource Trends

- Describes a Geographic Information System (GIS) database created for the Sukunka Case Study area from readily available government sources.
- Reviews land use, human activity, and renewable resource information to document historical trends and current conditions.
- Describes projections of future land use and human activity patterns and possible renewable resource availability, abundance, and distribution.

- Relates historical and future renewable resource trends to land use and human activity patterns and identifies apparent thresholds.

Section 4. Cumulative Effects Criteria and Thresholds

- Evaluates applicability of cumulative effects analyses and ecological, land use, and social thresholds in the Sukunka Case Study area.
- Evaluates utility of readily available data for cumulative effects models and assessments.

2. REGIONAL SETTING

The Sukunka Case Study area includes a 1,215 km^2 area southwest of Chetwynd (Figure 1). The Case Study area is bounded roughly by the Sukunka River to the south and east, Pine River on the north, Falling Creek to the northwest, and Goodrich Peak and Mount Merrick to the southwest (Figure 2).

The Sukunka Case Study area lies within the Central Rocky Mountains Ecoregion of the Sub-Boreal Interior Ecozone. This ecoregion encompasses the Hart Ranges and Foothills. The climate is characterized by cold snowy winters and warm summers (DeMarchi 1996). There is ample precipitation year-round, with a mean annual range of 500-700 mm. The annual mean temperature is about 1.5°C, with summer and winter temperature means of 12° and -10°, respectively (Environment Canada 2002). The region consists of steep-sided, round-topped mountains and foothills (DeMarchi 1996). Sporadic discontinuous permafrost exists at higher elevations. The Sukunka study area is within the Hart Foothills Ecosection, typified by low, rounded mountains and wide valleys. This is the driest ecosection in the Central Rocky Mountains Ecoregion (DeMarchi 1996).

In the Sukunka study area, local climatic conditions vary greatly because of the influence of mountainous terrain and elevation. In general, annual precipitation is inversely related to elevation. This affects winter wildlife distribution by confining them to relatively restricted valley bottoms, southerly exposed slopes, and windswept areas with reduced snow cover. Forest in the Sukunka Case Study area includes the transition between the Boreal White and Black Spruce biogeoclimatic zone (BWBS; *Picea glauca* and *P. mariana*) in the east, and the Sub-Boreal Spruce (SBS) and Engelmann Spruce–Subalpine Fir (ESSF; *Picea engelmannii-Abies lasiocarpa*) biogeoclimatic zones to the west. The Alpine Tundra (AT) biogeoclimatic zone occurs on the highest peaks above elevations of approximately 1,800 m.

The Hart Ranges, part of the Rocky Mountains, are underlain by Cambrian to Jurassic sedimentary rock. Soils have developed on glacial parent materials and are predominantly Luvisolic, with moderately acidic upper horizons (A and B) and an alkaline C horizon with low organic matter (MEM, MELP, and MOF 1999).

The BWBS biogeoclimatic unit occurs at elevations of approximately 600 m to 1,300 m. BWBS forests are characterized by lodgepole pine (*Pinus contorta*), white and black spruce, and trembling aspen (*Populus tremuloides*) interspersed with many bogs and fens. Highbush cranberry (*Viburnum edule*), rose (*Rosa* spp.), forbs and mosses are commonly found in the understory. This forest has potential for white or black spruce climax forest, but frequent fires have left few climax stands in the region (MEM, MELP, and MOF 1999).

The SBS biogeoclimatic unit occurs at slightly higher elevations (1,200 m to 1,800 m) than the BWBS zone, generally along the valley bottoms of smaller drainages. The dominant tree species are hybrid spruce and subalpine fir and extensive stands of lodgepole pine exist in the drier portions where fire has influenced forest succession (MEM, MELP, and MOF 1999).

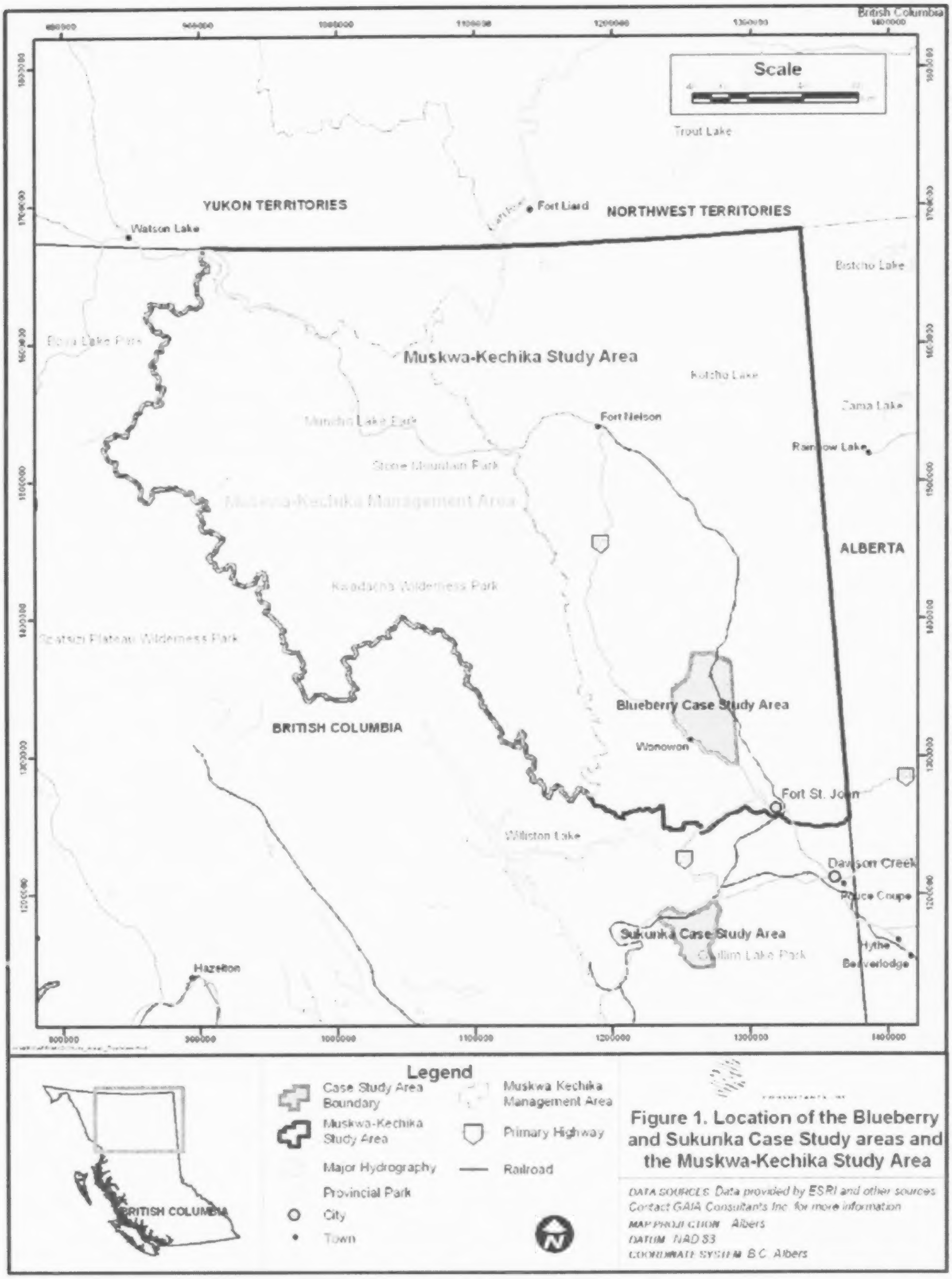


Figure 1. Location of the Blueberry and Sukunka Case Study areas and the Muskwa-Kechika Study Area

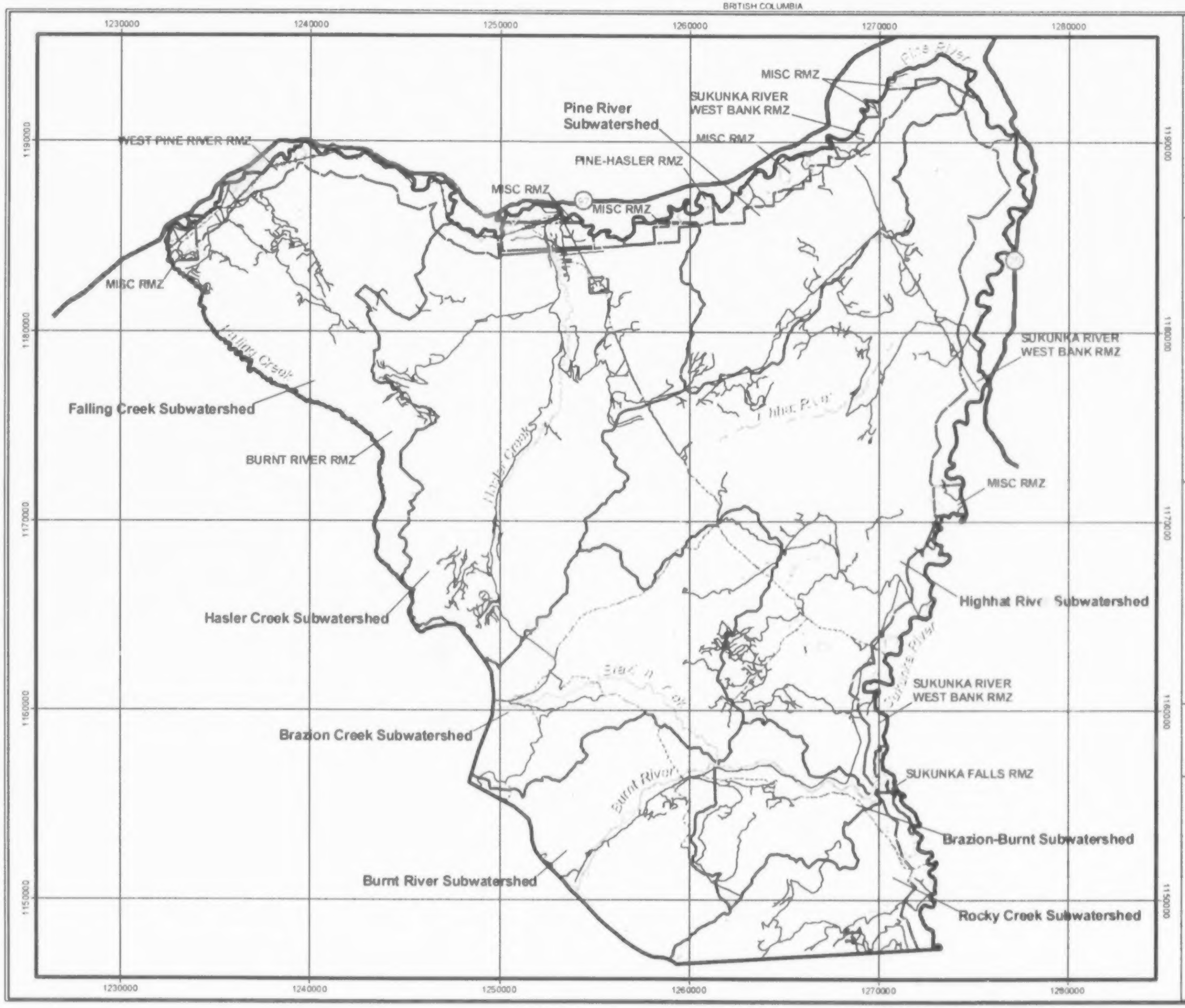
DATA SOURCES: Data provided by ESRI and other sources. Contact GAIA Consultants Inc. for more information
MAP PROJECTION: Albers
DATUM: NAD 83
COORDINATE SYSTEM: B.C. Albers

1st Edition

OGC

Figure 2

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Sukunka Case Study Area



LEGEND

- Study Area
- RMZ Boundary
- Subwatershed
- Primary Highway
- Secondary Road
- Rail Line
- Pipeline
- Hydrography
- Albers Coordinate Grid

Map Scale 1 200 000

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from a DEM. Primary Highway taken from ESRI maps and data.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

The ESSF biogeoclimatic unit is the most extensive in the Case Study area and occurs between elevations of 1,200 m to 1,800 m. Engelmann spruce and subalpine fir trees are the dominant tree species, which tend to grow in clusters interspersed with meadows, heath and grassland. (MEM, MELP, and MOF 1999). The AT unit has a harsh climate and supports few trees. This zone is dominated by dwarf shrubs, herbs and mosses.

The Sukunka study area is primarily (57%) within the watershed of the Sukunka River. The subwatersheds within the Sukunka River drainage include the Highhat River (29% of the study area), Brazion Creek and Burnt River (22% of the study area), and Rocky Creek 6% of the study area). The remainder of the Sukunka study area is within the Pine River drainage. Pine River subwatersheds include Hasler Creek (21% of the study area) and Falling Creek (9% of the study area; Figure 2).

2.1 ADMINISTRATIVE

The closest community is the town of Chetwynd located at the northeast corner of the study area. The City of Dawson Creek is located approximately 85 km to the east via all weather Highway 97. A wide variety of human activities occur in the Sukunka study area. Primary land uses are oil and gas exploration and development, forest harvest, trapping, and recreational and subsistence hunting and fishing. Grazing and agricultural development also occurs in the Pine and Sukunka river valleys.

Overall guidance for land and resource use is provided by the Dawson Creek Land and Resource Management Plan. Provisions of this plan and other applicable management guidance documents are summarized below.

2.1.1 Dawson Creek Land and Resource Management Plan

The Sukunka Case Study area lies within the Dawson Creek Land and Resource Management Planning (LRMP) area. The Dawson Creek LRMP covers all crown land within the Dawson Creek Forest District with the exception of the Kakwa Recreation Area. The planning area covers about 2.9 million hectares between the Peace River in the north, the Mackenzie Forest District to the west, the Prince George Forest District to the south and Alberta to the east (MEM, MELP, and MOF 1999).

In 1994, the population of the Dawson Creek Planning area was over 30,000 (MEM, MELP, and MOF 1999), two thirds of whom live in the communities of the City of Dawson Creek, District of Tumbler Ridge, District of Chetwynd, District of Hudson's Hope, and the Village of Pouce Coupe. The West Moberly and Saulteau First Nations and the Kelly Lake Metis Community also reside in the LRMP, which is covered entirely by Treaty 8. Access to the region is provided by the John Hart Highway (Highway 97), and scattered forestry and hydrocarbon exploration and development roads. Significant portions of the region remain unroaded (MEM, MELP, and MOF 1999).

The goal of the Dawson Creek LRMP is to provide a strategic planning framework for resource development and access to natural resources outside of Protected Areas, based on the principles of integrated resource management (MEM, MELP, and MOF 1999). The plan outlines objectives and strategies to manage and maintain the protection of environmental and resource values while providing greater environmental and economic stability for the region's communities and residents. Overall objectives (General Management Directions) include, among others:

- Conservation of biodiversity;
- Conservation of soil productivity;
- To sustain and manage of fish and wildlife habitat;
- Provision of sustainable fish and wildlife harvest opportunities;
- To meet or exceed provincial air quality standards;
- To sustain and manage recreational values, opportunities and activities;
- To avoid infringement of aboriginal and treaty rights and provide opportunities for pursuit of traditional resource uses;
- To maintain and provide agricultural and grazing opportunities;
- To provide opportunities for environmentally responsible exploration and development of coal, mineral, and hydrocarbon resources, hydroelectric power, and transportation, communication and utility infrastructure;
- To maintain or enhance sustainable forest resource management activities; and
- Maintenance and management of access to Crown lands.

The Dawson Creek LRMP area is divided into 12 resource management zones (RMZ's) based on a number of considerations such as topography, resource values, existing land use and access, etc. Each RMZ is classified into one of six Provincial Land Use Categories, providing the overall management regime. The Sukunka Case Study Area lies within the South Peace RMZ, which has been categorized into the **Enhanced Resource Development** general management regime. This Land Use category includes land:

- with existing or potential future intensive resource development;
- given high priority for a special or combined resource management focus (i.e. high intensity forest management); and
- where resource development and enhancement are encouraged with full compliance with existing regulatory requirements.

Natural resource (hydrocarbon, coal, and timber) extraction and development are important to the local economy within this RMZ (MEM, MELP, and MOF 1999).

The Sukunka Case Study Area falls entirely within the Burnt River Resource Management Subzone of the South Peace RMZ, part of wildlife Management Unit 7-22 (MU 7-22). Although few significant valued resources were identified specifically within the Burnt River Subzone, the foothills may provide habitat for grizzly bear (*Ursus* *arctos*), caribou (*Rangifer tarandus*), large and small mammals, and native fish. Two significant coal reserves have been identified within the Burnt River Subzone; there is moderate to high potential for natural gas reserves and timber harvesting in proximity to existing wood processing facilities. Resource Management objectives for the Burnt River Subzone generally follow the General Management Direction outlined above. Access management planning will involve large-scale coordination and joint use strategies along with small-scale application of access management planning to protect sensitive resource values (MEM, MELP, and MOF 1999).

Fish are present in the at least the middle and lower reaches of all streams in this area; bull trout (*Salvelinus confluentus*), mountain whitefish (*Prosopium williamsoni*), and Arctic grayling (*Thymallus arcticus*) are the most common species. Rainbow trout (*Oncorhyncus mykiss*) are present in Hasler Creek, Beaudette Creek, and the Burnt River. The Sukunka River is a regionally important sport fishery and is considered to have very high capability. Bull trout in the Sukunka River move into Martin, Baker, and Rocky creeks to spawn; spawning habitat is assumed to be a limiting factor for bull trout in this drainage (Antoniuk 1994).

The Burnt/Brazion system is used for feeding, spawning, and rearing by bull trout and mountain whitefish. Arctic grayling do not appear to spawn in this drainage. An impassable falls on the lower portion of the Burnt River was removed in the early 1980's, allowing large numbers of Arctic grayling to move further upstream during the summer to feed. Special size, catch and possession regulations have been implemented to protect both bull trout and Arctic grayling populations in the area. The Burnt River was designated a catch-and-release fishery following construction of the Burnt River resource road to prevent depletion of fish stocks. No creel census data are available, but angling effort is believed to be increased because of expanding access and ATV use (Antoniuk 1994).

2.1.2 Wildlife Management Plans

2.1.2.1 Provincial Wildlife Strategies

The Provincial Wildlife Strategy (MELP 1994) provides a framework for wildlife program planning and prioritization. Wildlife management will be based on the principles of ecosystems and population management using best available biological, ecological, and social information. Specified goals include:

- Maintain diversity and abundance of native species and their habitats throughout British Columbia.
- Provide a variety of opportunities for the use and enjoyment of wildlife.
- Balance needs of wildlife and needs of people.

The Wildlife Harvest Strategy (MELP 1996) provides the framework for management of game species. Species-specific management standards are provided for caribou, deer, elk

(*Cervus elaphus*), moose (*Alces alces*), black bear (*Ursus americanus*), grizzly bear, cougar (*Felis concolor*), wolf (*Canis lupus*), migratory game birds, upland game birds, and furbearers.

2.1.2.2 Regional Wildlife Plan for the Peace Sub-region

The Sukunka Case Study area covers the northeast third of provincial wildlife Management Unit 7-22 (MU 7-22). Harper (1988) prepared a regional wildlife management plan for the Peace sub-region that includes specific recommendations for MU 7-22. The following species-specific status and recommended management objectives and activities were provided for the Sukunka area:

Moose – Mid-1980's population in MU 7-22 is approximately 860 and stable to decreasing; population well below estimated habitat capability. Increase population in MU 7-22 by 25% to about 1,075 moose by the year 2000 and provide a hunter success rate of 40% with a moose killed for every 15 days hunted. To be achieved through habitat protection and enhancement, reducing non-hunting mortalities, and introducing an intensive inventory program to monitor population trends and regulate harvest.

Grizzly Bear – Mid-1980's population in MU 7-22 is approximately 145 with an annual allowable harvest of 5 bears. Maintain the grizzly bear population in MU 7-22 at current levels. To be achieved by regulating sport harvest to 2% females and 6% males, monitoring kill locations to avoid local overharvesting, and minimizing bear-human conflicts.

Caribou – Mid-1980's caribou population in MU 7-22 is approximately 80 and stable to increasing. Increase regional population to 2,500 (over 125%) by the year 2000 if predation is not limiting. To be achieved through regulated male-only harvest, restricting access roads and all-terrain vehicle access into alpine tundra habitats, regulating harvest of mature lodgepole pine stands, and intensive inventory to document population dynamics.

Elk – Mid-1980's caribou population in MU 7-22 is approximately 50 and stable to increasing; no sport harvest allowed (trophy bull season has subsequently been established). Increase the population in MU 7-22 to 300 by the year 2000. To be achieved through habitat protection, habitat enhancement and elk transplants in the Sukunka River valley, regulating harvest, and introducing an intensive inventory program to monitor population dynamics and trends.

Mule and White-tailed Deer (*Odocoileus hemionus and O. virginiana*) – 1987 mule deer population approximately 150 in MU 7-22, approximately half of estimated habitat capability. Deer populations to be maintained at, or slightly above current level. To be achieved through supplementary feeding during severe winters, harvest regulation, and protection of important winter ranges.

Black bear – Mid-1980's population in MU 7-22 is approximately 500 to 600. Reduce current regional populations by about 20% by controlling nuisance bears, minimizing bear-human conflicts, and adjusting harvest to manage the population size and distribution.

Wolf – Mid-1980's population estimated to be 20 to 30. Maintain wolf numbers within the agricultural area at current levels and allow numbers to fluctuate naturally in the rest of the sub-region. To be achieved by allowing generous harvest, and predator control assistance. In the Sukunka study area, wolf control to be provided only on private lands in the Pine River valley where livestock depradation occurs.

Furbearers – Mid-1980's population status for 15 furbearer species unknown. Lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), fisher (*Martes pennanti*), and river otter (*Lontra canadensis*) are considered to be vulnerable to overharvest. Manage harvest with minimum regulatory control, high measure of responsibility on the Registered Trapline holder, and habitat protection through referral system.

Non-game wildlife – Management efforts to concentrate on species of concern (endangered, restricted distribution, management concern). Systematically monitor a variety of non-game species and specialized habitats (e.g., riparian balsam poplar (*Populus balsamifera*) communities, wetlands, large snags for cavity nesters) and protect key habitats through referral system.

2.1.2.3 Identified Wildlife Management Strategy

Bull trout, fisher, grizzly bear, and northern goshawk (*Accipiter gentilis*) are classified as 'Identified Wildlife' under the Forest Practices Code (see Section 2.1.3.1). The goals of the Identified Wildlife Management Strategy are to minimize the effects of forest activities on Identified Wildlife, to maintain their limiting habitats throughout their current ranges and, where appropriate, their historic ranges. In some cases, this will entail restoration of previously occupied habitats, particularly for those species most at risk.

Identified Wildlife are managed through the establishment of wildlife habitat areas (WHAs) and implementation of general wildlife measures (GWMs) as specified in 'Managing Identified Wildlife: Procedures and Measures Volume 1 (MOF 1999). The purpose of WHAs is to conserve those habitats considered most limiting to a given species. GWMs describe the management practices that must be implemented within an approved WHA such as seasonal or year-round activity restrictions.

Identified Wildlife provisions are typically site-specific measures that cannot address the issues of habitat supply, habitat connectivity and population viability. Such considerations are considered in landscape level or regional plans such as the FSJ LRMP or MKMA Management Plan. Species-specific or higher level plans may be developed where provincial authorities determine that additional measures are required to conserve viable populations of a species throughout its range in British Columbia.

2.1.2.4 Provincial Species Management Strategies

Species management strategies and plans developed by the provincial government provide guidance for the following species of concern:

- British Columbia Grizzly Bear Conservation Strategy (MELP 1995.
- A Lynx Management Strategy for British Columbia (Hatler 1988).
- A Wolverine Management Strategy for British Columbia (Hatler 1989).

2.1.3 Other Management Initiatives

Other initiatives that affect resource management in the Ft. St. John planning area include the Forest Practices Code, the Oil and Gas Handbook, and First Nations interests, among others (ARA Consulting et al. 1996). Theses are discussed briefly below.

2.1.3.1 Forest Practices Code

A series of regulations, standards, and guidebooks have been developed since 1994 pursuant to the *Forest Practices Code of British Columbia Act* (the Forest Practices Code). One of the key objectives of the Code is to ensure that long-term environmental considerations are taken into full account.

Standards set out detailed requirements for activities in forested areas, including soil conservation, road and bridge construction, timber harvesting, and access management. A series of guidebooks have been prepared to help land users develop site-specific plans.

2.1.3.2 Oil and Gas Handbook

The Oil and Gas Commission has developed a series of Guidelines, Policies, Information Letters, and Information Bulletins that provide guidance on oil and gas exploration, development, and production activities in the Sukunka area. The Oil and Gas Handbook summarizes legislative requirements, regulations, procedures, and guidelines for proposed oil and gas activities and provides a starting point from which proponents can plan and undertake activities, acquire additional reference material or contact government personnel and industry associations for further assistance.

The 'Maximum Disturbance Review Criteria Operating Code and Guideline' (OGC 2002) defines acceptable siting/routing, size, spacing, and construction techniques for oil and gas development activities. Guidelines for minimum construction setbacks from sensitive habitat features are provided.

2.1.3.3 First Nations Interests

The Sukunka Case Study area is within the traditional territories of the Saulteaux and West Moberly First Nations. Relationships with First Nations in this region are affected by the circumstances surrounding land claims in general, Treaty 8 in particular, recent court decisions regarding aboriginal rights, and Memoranda of Understanding negotiated between First Nations and the Province.

First Nations did not participate in the Dawson Creek LRMP process, and direct consultation with potentially affected groups is generally required before commencing industrial activities on forested Crown lands in the Sukunka area.

3. DEVELOPMENT AND RESOURCE TRENDS

This discussion of development and renewable resource trends in the Sukunka Case Study area is divided into three subsections:

Section 3.1 Mapping and Analysis Methods

- Summarizes methods used to develop the GIS database and wildlife habitat models, and complete cumulative effects analyses.

Section 3.2 Development Trends

- Describes changes land use and human activity and anthropogenic disturbance trajectories in the Sukunka area since 1950.
- Describes projections of future land use and human activity patterns for the Sukunka area.

Section 3.3 Renewable Resource Trends

- Describes changes in fish and wildlife populations and habitat in the Sukunka area since 1969.
- Describes projections of future renewable resource availability, abundance, and distribution.
- Relates historical and future renewable resource trends to land use and human activity patterns and identifies apparent thresholds.

3.1 MAPPING AND ANALYSIS METHODS

3.1.1 Geographic Information System

A Geographic Information System (GIS) database was developed for the Sukunka Case Study area by GAIA in ARCView© and ARCInfo©. This database used readily available 1:20,000 digital TRIM files provided by regional government staff, including: elevation, hydrography, forest cover, base features (roads, cutlines, pipelines, railway lines, facilities, clearings, communities), and LRMP management boundaries. Watershed and subwatershed boundaries were derived in the GIS using the digital elevation model.

3.1.2 Development and Renewable Resource Trends

Land use patterns in the Sukunka area were identified at three points in time: 1969, 1981, and current (late 1990's). Base features in 1969 and 1981 were digitized from air photographs. Current (late 1990's) conditions were obtained from TRIM files.

Harper (1988) provides the most comprehensive record of wildlife status in the Sukunka area. Hunter and trapper harvest and effort data for MU 7-22 was obtained from WLAP regional staff to document recent trends in wildlife and furbearer harvest and inferred abundance.

WLAP files were also searched to obtain any relevant information on historical fish and wildlife distribution and abundance and human activity patterns.

3.1.3 Wildlife Habitat Models

Habitat models describe or predict the physical and biological factors that are assumed to control the distribution and abundance of wildlife and fish populations. The primary purpose of habitat models is to provide a relative rating of the importance of specific vegetation or biogeoclimatic units for a particular wildlife species (Salmo et al. 2001).

3.1.3.1 Species Selection

Every species has some value for assessing environmental conditions and potential effects. However, evaluating every species in a cumulative effects assessment is impractical. An accepted approach is to select a complementary suite of representative species, groups, or guilds that are useful in quantifying or evaluating the effect of disturbance (Beanlands and Duinker 1983; Noss 1990; Cocklin et al. 1992; Smit and Spaling 1995; Noss et al. 1996). Appropriate species or guilds used for cumulative effects assessment and management are generally selected by considering the following criteria (adapted from Noss 1990):

- economic importance (e.g., **featured** species important for hunting, fishing, traditional land use, or recreation),
- sensitivity to potential development activities or early indicator of environmental stress or incremental demand on facilities and services (e.g., **ecological** and **sensitive** indicators: species that signal the effects of perturbations on a number of species with similar habitat requirements),
- importance in the food chain or ecosystem function (e.g., **keystones**: pivotal species upon which the diversity of a large part of a community depends),
- social importance (e.g., **flagships**: popular, charismatic species that serve as symbols and rallying points for conservation initiatives),
- special conservation status (e.g., **vulnerables**: species that are rare, genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise vulnerable to extinction in human-dominated landscapes),
- ecological or economic significance for more than one discipline and disturbance type (e.g., **umbrellas**: species with large area requirements that incorporate many other species).

- ability to be quickly and cost-effectively calculated, estimated or assessed from existing data sources, and
- ability to be efficiently and cost-effectively monitored.

The four wildlife species selected as indicators for the Blueberry and Sukunka Case Studies: moose, woodland caribou, elk, and grizzly bear, are high profile or sensitive species for which reasonable data are available. Representative fish (Arctic grayling and bull trout), furbearer (marten, *Martes americana*), and forest bird species (black-throated green warbler, *Dendroica virens*) were also considered for suitability modelling. However, because there were limited or no historical data available, cumulative effects on these animals were not specifically evaluated.

Moose and elk are moderately abundant in both study areas and represent habitat generalists that are relatively tolerant of human disturbance. Woodland caribou and grizzly bear were selected because they are intolerant of human disturbance and generally require large areas of suitable habitat. The 'umbrella species' concept suggests that protection of habitat values and linkages for these large vertebrates will also provide protection for more than 90% of other species found in foothills areas (reviewed in Paquet and Hackman 1995).

3.1.3.2 Suitability Ratings

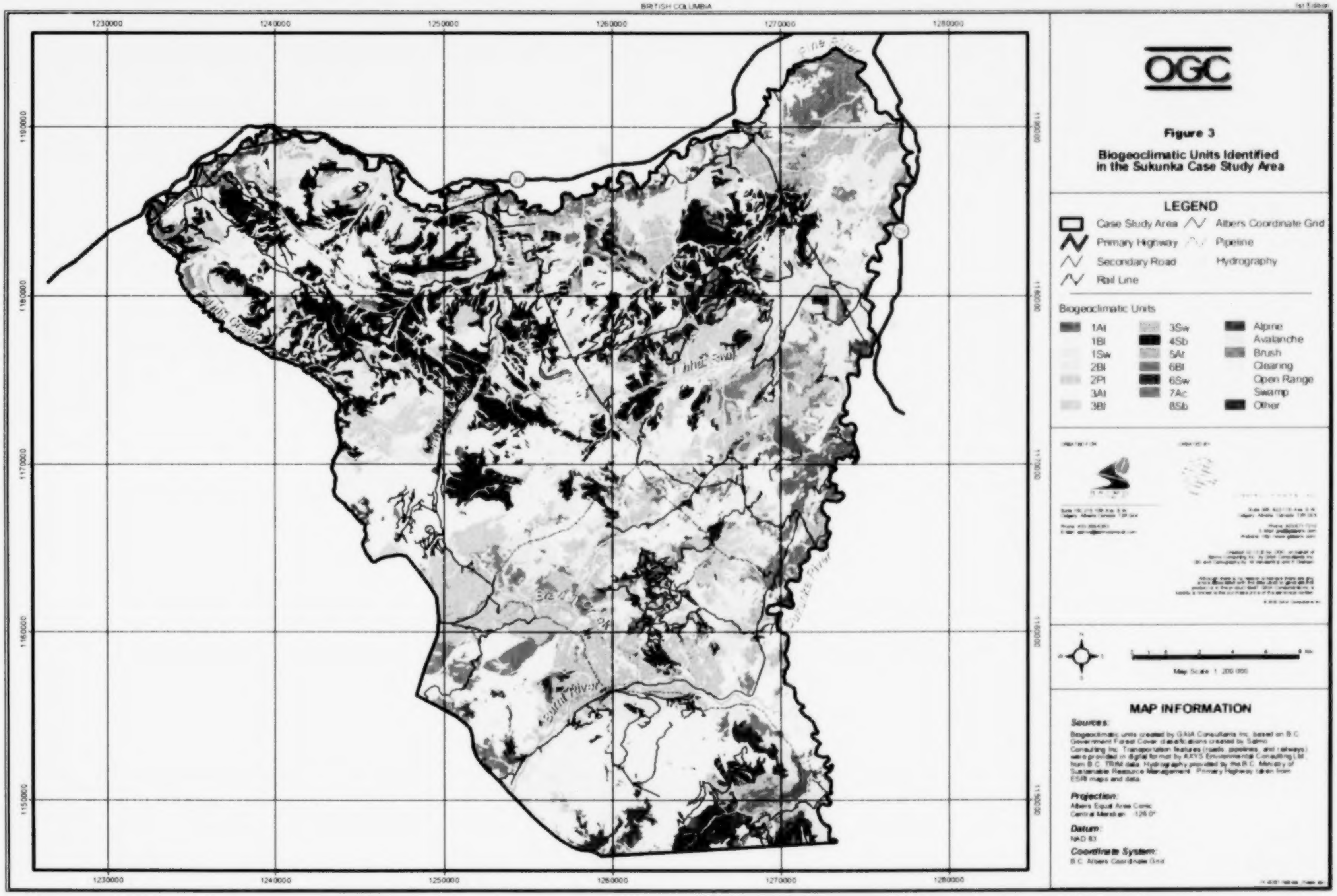
Habitat suitability is the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (Demarchi et al. 1990). Ratings of **habitat capability** have been developed for northeast British Columbia by provincial sources. Capability is defined as the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999). Habitat suitability ratings are most commonly used for cumulative effects assessments (Hegmann et al. 1999).

Overall habitat suitability ratings were developed for 4 wildlife species (moose, grizzly bear, caribou, and elk) using habitat units defined from forest cover data. Tree species dominance (primary, second, third, fourth) attributes identified 124 different combinations present in the Sukunka area. These were combined into 15 Biogeoclimatic units (site series) based on descriptions provided in Delong (1988), DeLong et al. (1990, 1994). An 'Avalanche chute' unit delineated from the most recent air photos was also added. Habitat units are summarized in Table 1 and depicting visually in Figure 3.

One of 7 age classes was then applied to each habitat unit using the Projected Age attribute included with forest cover data. Habitat suitability ratings for the 4 species were then applied for each Biogeoclimatic unit and age class as shown in Table 2. A four-class suitability rating system (High, Moderate, Low, Nil) appropriate for an intermediate level of knowledge was adopted (RIC 1999). Habitat suitability ratings were based on those

Table 1. Habitat Unit Area Summary for the Sukunka Case Study area.

BioGeoclimatic Unit	Area (ha)								% of Study Area
	Forest Seral Stage (age in years)							Total	
BSBW Unit	0-5	6-15	16-25	26-40	41-80	81-140	141+		
1At	10.10	118.69	0.00	59.09	2603.69	1044.55	169.85	4005.97	3.3
1Sw	167.50	129.82	69.50	1044.73	7093.33	9125.94	345.39	17976.21	14.8
2Pl	238.18	4578.13	0.00	1218.66	8113.60	1694.12	25.45	15868.14	13.1
3At	39.09	0.00	0.00	762.38	2338.35	138.73	0.00	3278.55	2.7
3Sw	44.58	107.24	0.00	492.37	2820.59	1630.33	0.00	5095.11	4.2
4Sb	0.00	96.33	53.80	330.66	3898.43	14758.23	276.25	19413.70	16.0
5At	0.00	80.20	0.00	46.74	743.32	428.92	0.00	1299.18	1.1
6Sw	239.34	7.97	0.00	0.00	70.21	728.05	94.69	1140.26	0.9
7Ac	0.00	1.73	0.00	2.73	0.00	423.98	0.00	428.44	0.4
8Sb	0.00	0.00	0.00	0.00	101.33	169.34	63.85	334.52	0.3
ESSF Unit									
1Bl	937.59	499.70	184.41	281.50	4883.83	16724.81	8715.19	32227.03	26.5
2Bl	271.75	0.00	0.00	0.00	1357.58	1443.00	0.00	3072.33	2.5
3Bl	0.00	0.00	24.90	141.96	552.9	2904.24	168.68	3792.68	3.1
6Bl	0.00	0.00	0.00	0.00	0.00	0.00	41.60	41.60	0.0
Alpine Forest									
AT Unit									
Alpine	914.35	0.00	0.00	0.00	0.00	0.00	0.00	914.35	0.8
Avalanche Chute	5.11	0.00	0.00	0.00	0.00	0.00	0.00	5.11	0.0
Non-Specified									
Brush	10054.57	0.00	0.00	0.00	0.00	0.00	0.00	10054.57	8.3
Clearing	640.05	0.00	0.00	0.00	0.00	0.00	0.00	640.05	0.5
Meadow									
Open Range	81.50	0.00	0.00	0.00	0.00	0.00	0.00	81.50	0.1
Other	1084.49	0.00	0.00	0.00	0.00	0.00	0.00	1084.49	0.9
Swamp	734.72	0.00	0.00	0.00	0.00	0.00	0.00	734.72	0.6
Total	15462.92	5619.81	332.61	4380.82	34577.16	51214.24	9900.95	121488.50	
% of study area	12.73	4.62	0.27	3.60	28.46	42.16	8.15	100.00	100.0



OGC

Figure 3

Biogeoclimatic Units Identified in the Sukunka Case Study Area

MAP INFORMATION

Sources:

Biogeoclimatic units created by GAIA Consultants Inc. based on B.C. Government Forest Cover classifications created by Salmo Consulting Inc. Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. Hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

Table 2. Wildlife suitability ratings used in the Sukunka Case Study area.

BioGeoclimatic Unit	Moose							Grizzly Bear						
	Forest Seral Stage (age in years)							Forest Seral Stage (age in years)						
BSBW Unit	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**
1At		High	High	Mod.	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
1Sw		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.		Low	Low	Low	Mod.	Mod.	Mod.
2Pl		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Low	Low
3At		High	High	High	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
3Sw		Low	Mod.	Mod.	Mod.	Low	Low		Low	Low	Low	Mod.	Mod.	Mod.
4Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
5At		High	High	High	Mod.	Mod.	Mod.		Mod.	Mod.	Low	Low	Low	Low
6Sw		Low	Mod.	Mod.	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Low	Low
7Ac		High	High	Mod.	Mod.	Low	Low		High	High	High	High	High	High
8Sb			Mod.	Mod.	Mod.	Mod.	Mod.		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
ESSF Unit														
1Bl		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Mod.	Mod.
2Bl		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Mod.	Mod.
3Bl		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Mod.	Mod.
6Bl		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Mod.	Mod.
Alpine Forest	Mod.							Mod.						
AT Unit														
Alpine	Low							Mod.						
Avalanche Chute														
Non-Specified														
Brush	Low							Low						
Clearing	Low							Low						
Meadow	Low							Mod.						
Open Range	Low							Low						
Other	Nil							Nil						
Swamp	Mod.							Nil						

Table 2. Wildlife suitability ratings used in the Sukunka Case Study area (cont'd).

BioGeoclimatic Unit	**Caribou**							**Elk**						
	Forest Seral Stage (age in years)							**Forest Seral Stage (age in years)**						
BSBW Unit	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**	**0-5**	**6-15**	**16-25**	**26-40**	**41-80**	**81-140**	**141+**
1At		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
1Sw		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
2Pl		Low	Low	Low	Mod.	Mod.	3		Low	Low	Low	Low	Low	Low
3At		Nil	Nil	Nil	Nil	Nil	Nil		High	High	Mod.	Mod.	Mod.	Mod.
3Sw		Low	Low	Low	Low	Mod.	Mod.		Low	Mod.	Low	Low	Low	Low
4Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
5At		Low	Low	Low	Low	Low	Low		High	High	Mod.	Mod.	Mod.	Mod.
6Sw		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
7Ac		Low	Low	Low	Low	Low	Low		Mod.	Mod.	Low	Low	Low	Low
8Sb		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
ESSF Unit														
1Bl		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
2Bl		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
3Bl		Low	Low	Low	Low	Mod.	Mod.		Low	Low	Low	Low	Low	Low
6Bl		Low	Low	Low	Low	Low	Low		Low	Low	Low	Low	Low	Low
Alpine Forest	Low							Low						
AT Unit														
Alpine	High							Low						
Avalanche Chute														
Non-Specified														
Brush	Nil							Low						
Clearing	Nil							Low						
Meadow	Nil							Mod.						
Open Range	Nil							Low						
Other	Nil							Nil						
Swamp	Nil							Nil						

developed for the Westcoast Energy Inc. Grizzly Valley Expansion Project (Axys et al. 1994).

Limited information on Non-Forest and Non-Productive Forest Units was provided with the forest cover data, and these units assumed to be 0 to 5 years (age class 1). Habitat suitability ratings were applied for Alpine, Alpine Forest, Brush (defined as Non-Commercial, Non-Productive, Non-Productive Brush, and Non-Commercial Brush types), Clearing, Open Range, and Swamp types. Other Non-Forest and Non-Productive Forest types, including Clay Bank, Gravel Bar, Lake, River, and Urban/Roads were assumed to have Nil suitability for all species (Table 2).

Trends in the availability of high and moderate suitability habitat were estimated for each species by RMZ. This was done by using the land use layer developed for each time period to calculate the area affected by direct disturbance.

Trends in the availability of relatively undisturbed 'core' habitat were also estimated in a similar manner. A zone of influence (GIS buffer) of 500 m was applied to all potentially 'high use features' (roads, trails, pipelines, railway lines, well sites, communities, and clearings) to represent the area where reduced habitat effectiveness could occur. Residual core areas with high and moderate suitability were then calculated for each species by RMZ.

Use of a 500 m wide zone of influence for most features is considered to be conservative because avoidance is generally related to the level of activity rather than the features themselves (Mattson 1993; Dyer 1999; Gibeau 2000). Core area analyses undertaken for grizzly bears in Alberta have applied a 500 m zone of influence to high use features only (>100 parties per month; Gibeau et al. 1996; ESGBP 1998; Kansas and Collister 1999; Gibeau 2000). Studies conducted in the Alberta foothills show that off-road vehicle use of cutlines, pipelines, and old resource roads are generally lower than previously estimated (CRC 1999). In a 1,200 km^2 area southeast of Hinton, less than 40% of roads and only 3% of trails were classified as high use (average greater than 20+ vehicle parties per week). Most cutlines, old forestry and petroleum roads, and utility corridors averaged less than one vehicle pass per week (classified as no use for grizzly bear habitat effectiveness purposes; Kansas and Collister 1999; Salmo unpub. data). Given the comparatively low population density in the Fort St. John region, human use of most cutlines, pipeline rights-of-way, and old resource road is expected to be similar or lower in the Sukunka Case Study area.

3.1.4 Land Use Indices

Suitable cumulative effects indices and thresholds used elsewhere were tested using information obtained from the historical data review.

3.1.4.1 Access Density

Access density trends were calculated for each type of linear feature (primary roads, secondary roads, truck trails, pipelines, rail lines, cutlines) using the land use layer developed for each time period. Access density can vary dramatically within a relatively small area, so independent estimates were calculated using a 'moving window' comprised of a 1 km by 1 km grid. Basic statistical estimates (range and average) of access density were generated for each RMZ and subwatershed. Total road and trail density was also calculated for combined primary roads, secondary roads, and truck trails.

3.1.4.2 Cleared/Disturbed Area

Total cleared or disturbed area was selected as a numerical index of terrestrial habitat availability and fragmentation of the forest land base. Total cleared or disturbed area was calculated for all linear features using specified right-of-way widths: roads and utility corridors (20 m); truck trails and cutlines (8 m). Well sites were assumed to average 1.5 ha in size and the size of other clearings was obtained from readily available data sources. Facilities and roads were identified from TRIM II digital files or historical aerial photographs. Cleared/disturbed area estimates were also calculated by RMZ and subwatershed for comparative purposes.

3.1.4.3 Edge and Core Area

Edge and core area were calculated to provide complementary analyses of disturbance-influenced and relatively undisturbed areas, respectively. For comparative purposes, these estimates were derived for each RMZ, subwatershed, and time period.

Total edge area was calculated by applying an assigned 'buffer' on each side of linear features and around cleared areas. The area within the edge buffer was then calculated for each time period, RMZ, and subwatershed. Edge width was assigned based on feature size and assumed human use intensity. Primary and secondary roads, well sites, and communities were assumed to be 'high use features' and were buffered by 500 m. Truck trails, pipelines, railway lines, and clearings were considered to be 'low use' features and were buffered by 250 m. Cutlines were considered to be 'no use' features and were not buffered.

Core areas were identified as those areas greater than 500 m from disturbance features (including primary and secondary roads, truck trails, pipelines, railway lines, well sites, petroleum and industrial facilities, residences, communities, and unspecified clearings). As noted previously, this is assumed to provide a conservative (i.e., worst-case) estimate.

Core area sizes were compared with minimum home range size or established core area thresholds to assess their suitability for specific species.

3.1.4.4 Stream Crossing Index

A 'stream crossing index', calculated as the number of crossings per km of stream, was used as a numerical indicator of potential aquatic disturbance. The watercourse network was based on digital TRIM II data. A stream crossing index was calculated independently for each linear feature and for combined roads, truck trails, and utility corridors in each RMZ and subwatershed. For evaluation purposes, stream index values were compared to data from foothills areas of British Columbia and Alberta.

3.1.4.5 Riparian Roads

An estimate of riparian area cleared was calculated by multiplying specified right-of-way widths: roads and utility corridors (20 m); truck trails and cutlines (8 m) and a riparian zone width of 30 m (15 m on each bank) for each stream and lake (Chilibeck et al. 1992; Harper and Quigley 2000). Estimates were derived for each RMZ, subwatershed, and time period for comparative purposes.

3.1.4.6 Cleared Riparian Area

An estimate of riparian area cleared was calculated by multiplying specified right-of-way widths: roads and utility corridors (20 m); truck trails and cutlines (8 m) and a riparian zone width of 30 m (15 m on each bank) for each stream and lake (Chilibeck et al. 1992; Harper and Quigley 2000). Estimates were derived for each RMZ, subwatershed, and time period for comparative purposes.

3.2 DEVELOPMENT TRENDS

Resource development is the primary land use objective in the Sukunka Case Study area (MEM, MELP and MOF 1999). Dominant land uses include petroleum exploration and development, forest harvest, grazing, and agriculture. All-weather and winter trails provide access to portions of the area.

3.2.1 Petroleum Activity

The energy industry is the largest economic sector in northeast B.C. Petroleum activity increased in this region in the late 1940's and oil and gas exploration and development has continued cyclically since that time. Approximately 12,000 wells have been drilled in northeast British Columbia, resulting in the identification of over 1,700 oil and gas pools. On average, 275 wells have been drilled each year since 1960. Exploration activity has intensified in the last ten years, with an average of just under 480 wells per year (Figure 4).

Seismic activity records are available only since 1982, but activity over this 20 year period has also continued cyclically (Figure 5). Since 2000, the level of proposed seismic activity has been three times greater than the 1982 to 1999 average.

Natural gas is processed at more than 20 small and large facilities located in the region, many of which recover sulphur and liquids. Oil and gas infrastructure and activity are concentrated in three development areas: Dawson Creek, Fort St. John, and Fort Nelson.

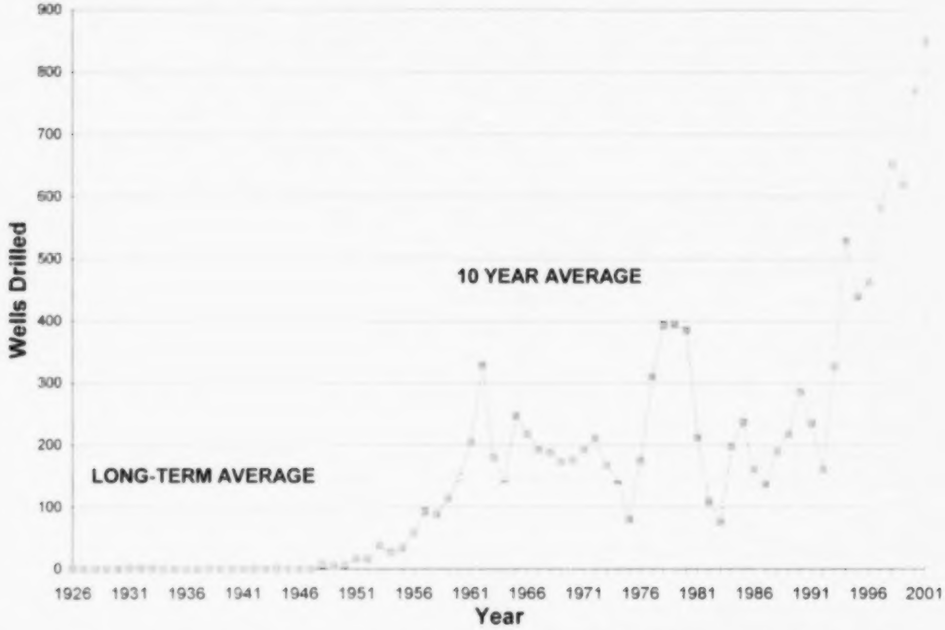


Figure 4. Annual wells drilled in northeast British Columbia, 1926 – 2001.

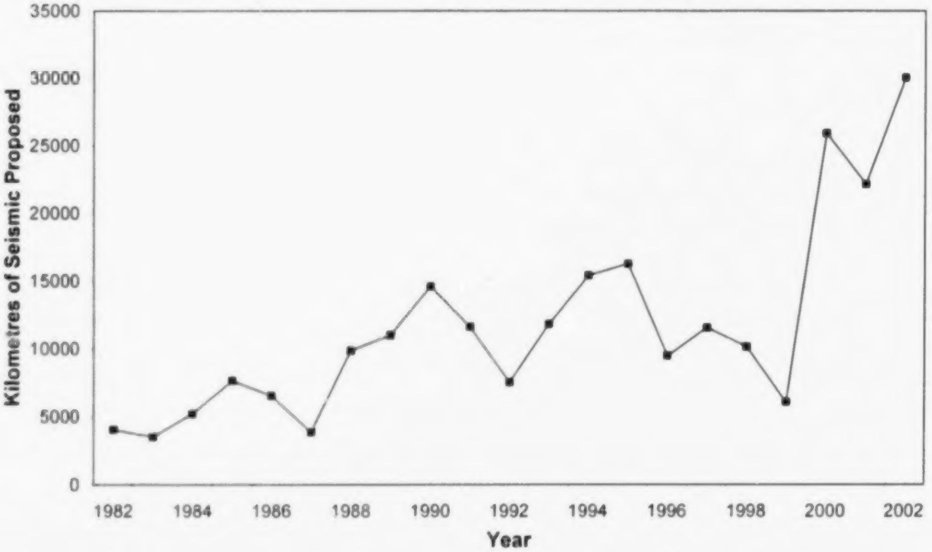


Figure 5. Yearly seismic kilometres proposed in British Columbia, 1982-2002.

The Sukunka Case Study area is located in the Dawson Creek development area where the Westcoast Energy Inc. Pine River sour gas plant is the largest facility. This plant was built in 1979 and processes gas from the Burnt, Brazion, and Sukunka fields in the Sukunka study area, as well as the Bullmoose, Murray, and Grizzly production areas to the south (the Pine River gas supply area). Oil and gas fields east of the Pine River gas supply area are tied into pipelines that ultimately carry these products into Alberta.

The Sukunka area was first developed in the late 1970's and currently has active natural gas tenures and some natural gas infrastructure, although it is much less developed than the Blueberry Case Study area. Historical petroleum activities in the Sukunka area are reviewed in Antoniuk (1994). Potential natural gas reserves are moderate to high.

Table 3 summarizes the changes in oil and gas infrastructure that have occurred in the Sukunka study area since 1969.

Table 3. Petroleum development trends in the Sukunka study area.

Feature	1969		1981		Current [2]	
	No. or km	Area (ha)	No. or km	Area (ha)	No. or km	Area (ha)
Secondary Roads[1]	104	190	391	710	782	1,432
Truck Trails	194	135	286	195	341	232
Wellsites	1	2	12	19	34	51
Cutlines	105	80	477	363	738	553
Pipelines	0	0	43	63	107	172
Total	-	407	-	1,350	-	2,440

[1] Includes secondary roads attributable to all economic sectors.
[2] Data are from the late 1990's.

On average, approximately 1 well and 23 km of secondary roads, 5 km of truck trails, 21 km of cutline, and 4 km of pipeline have been constructed each year since 1969 in the Sukunka area. Average construction rates for wells have increased since 1981 to approximately 2 wells per year. Development rates for secondary roads and pipelines have remained consistent, while development rates for truck trails and cutlines have declined respectively to 3 km and 15 km per year.

Historical oil and gas development activities and interviews with shipper representatives were used to forecast likely geophysical and field development activities associated with the Westcoast Energy Inc. Pine River Expansion Project proposed in 1993. Based on historical development patterns, 6 km of road and 2.1 km of pipeline have been associated with each well in the Burnt/Brazion and Sukunka gas catchment areas. Predicted average annual future activity rates in the Sukunka area were 3 wells, 15 km of roads, 140 km of cutlines, and 18 km of pipeline (Antoniuk 1994). This forecast occurred during the early 1990's peak, and likely overestimates current development rates.

3.2.2 Forest Harvest and Conversion

Forestry values in the Sukunka Case Study area are high; it is entirely within the 6,435 km^2 Tree Farm Licence 48 (TFL 48) issued to Canadian Forest Products Ltd. (Canfor). Eighty-nine percent of this area is considered to be productive forest. Spruce, lodgepole pine, balsam poplar, subalpine fir, and aspen harvested from TFL 48 are processed at Canfor's sawmill in Chetwynd and Lousiana-Pacific's pulpmill near Chetwynd.

The Timber Supply Analysis in the Dawson Creek Forest District recommended a constant harvest of coniferous timber, but decreased harvest of deciduous timber (MOF 1996). The Allowable Annual Cut (AAC) for TFL 48 was recently increased by 11 percent to 580,000 m^3. The total includes 55,000 m^3 deciduous and deciduous leading, and the balance in coniferous and coniferous-leading. The Small Business Forest Enterprise Program is allocated approximately 59,000 m^3 of the AAC. This AAC is considered to be sustainable for at least 20 years (MOF 2001)

The Sukunka study area contains valuable timber resources, and harvesting has been extensive in the Falling Creek, Highhat River, and upper Hasler Creek, Brazion Creek, and Burnt River subwatersheds. Canfor plans to continue to harvest timber from clearcut blocks in these areas (Antoniuk 1994).

Forest clearing trends in the Sukunka study area are summarized in Table 4. The average harvest rate over the last 28 years is estimated to be 174 ha per year in the Burnt River RMZ.

Table 4. Forest clearing trends in the Sukunka study area (ha).

Feature	1969	1981	Current[2]
Clearings[1]	321	1,208	5,179

[1] Includes undefined clearings in the Burnt River RMZ.

[2] Data are from the late 1990's

3.2.3 Agricultural Development

Agricultural activities in the Sukunka area are largely restricted to the larger river valleys near Chetwynd. Grazing permits are issued in the upper Sukunka River and Pine River valley at the south and northeast ends, respectively of the study area. Agricultural clearing trends in the Sukunka study area are summarized in Table 5. The average agricultural forest conversion rate over the last 28 years has been low, and is estimated to be 13 ha per year in the Pine-Hasler, West Pine, and Miscellaneous RMZs.

Table 5. Agricultural clearing trends in the Sukunka study area (ha).

Feature	1969	1981	Current[2]
Clearings[1]	57	263	429

[1] Includes undefined clearings in the Pine-Hasler, West Pine, and Misc. RMZs

[2] Data are from the late 1990's

3.2.4 Land Use Trends

3.2.4.1 Landscape Disturbance

Current infrastructure in the Sukunka Case Study area is shown on Figure 2, included previously in Section 2.1. Charts depicting trends in disturbance features and residual core areas calculated for the Sukunka case study area are provided below for each landscape index. Data used to generate these charts are summarized in Appendix A of this report.

3.2.4.2 Access Density

Access density plots for the Sukunka study area are provided by RMZ in Figure 6 and by subwatershed in Figure 7. No primary roads are present in this area, so reported road values consist entirely of secondary roads.

In 1969, linear features in the Sukunka study area included approximately 104 km of roads, 194 km of truck trails, 50 km of railway line, and about 105 km of cutlines. At this point in time, there were no pipelines in the Sukunka study area. Expressed as access density, in 1969 the overall Sukunka area had 0.22 km/km^2 of linear disturbances, including an average of 0.08 km/km^2 of roads, 0.15 km/km^2 of truck trails, 0.04 km/km^2 of railway lines, and 0.08 km of cutlines per km^2. Median values for all corridor types were 0, indicating that more than half of the Sukunka study area remained undisturbed at this point in time.

By 1981, the Sukunka study area contained 391 km of secondary roads, 286 km of truck trails, about 43 km of pipelines, 50 km of railway line, and 477 km of cutlines. This equates to an average corridor density of 0.29 km/km^2 of roads, 0.21 km/km^2 of truck trails, 0.07 km/km^2 of utility corridors (pipelines and railway lines), and 0.36 km/km^2 of cutlines. The overall Sukunka study area had 0.51 km/km^2 of linear features. In 1981, the median value for all corridor types remained at 0.

By the late 1990's, these numbers had increased to 782 km of secondary roads, 341 km of truck trails, 107 km of pipelines, and 738 km of cutlines. No new railway lines had been constructed since 1981. Expressed as average corridor density, the Sukunka area now supports 0.59 km/km^2 of roads, 0.26 km/km^2 of truck trails, 0.12 km/km^2 of utility corridors, and 0.55 km/km^2 of cutlines. Overall, the Sukunka study area had 0.84 km of linear corridors per km^2. See Figure 3 for a graphic representation of the change in corridor density over the three time intervals over the entire study area, and by individual RMZs and watersheds. Median cutline density is 0.3 km/km^2; median values for all other corridor types remain at 0.

3.2.4.3 Generalized Road Density Ratings

Quigley et al. (1996) established categories to rank road density in the Interior Columbia Basin of the Pacific Northwest. Table 6 summarizes trends in combined road and truck trail density within the Sukunka Case Study area using these categories. Average overall road density in the Sukunka study area increased from Low (0.22 km/km^2) in 1969 to Moderate (0.51 km/km^2) in 1981. In 2000, average road density remained Moderate (0.84 km/km^2).

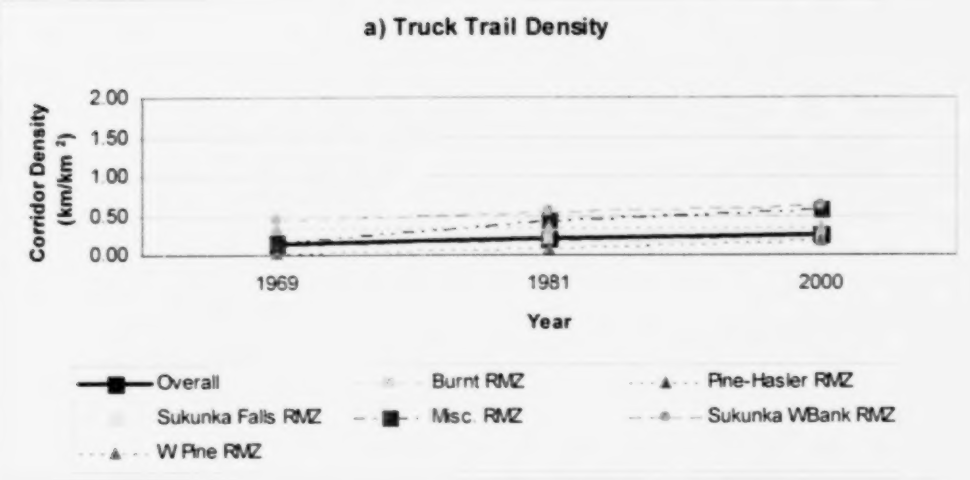
Table 6. Road and trail density trends in the Sukunka Case Study area.

Category	Road Density (km/km^2)	Percent of Study Area		
		1969	1981	Current*
Very Low	0.0 to 0.06	82.0	62.7	47.9
Low	>0.06 to 0.4	3.6	7.0	7.3
Moderate	>0.4 to 1.1	6.4	12.1	14.2
High	>1.1 to 2.9	7.1	15.2	24.3
Extremely High	>2.9	0.9	2.9	6.3

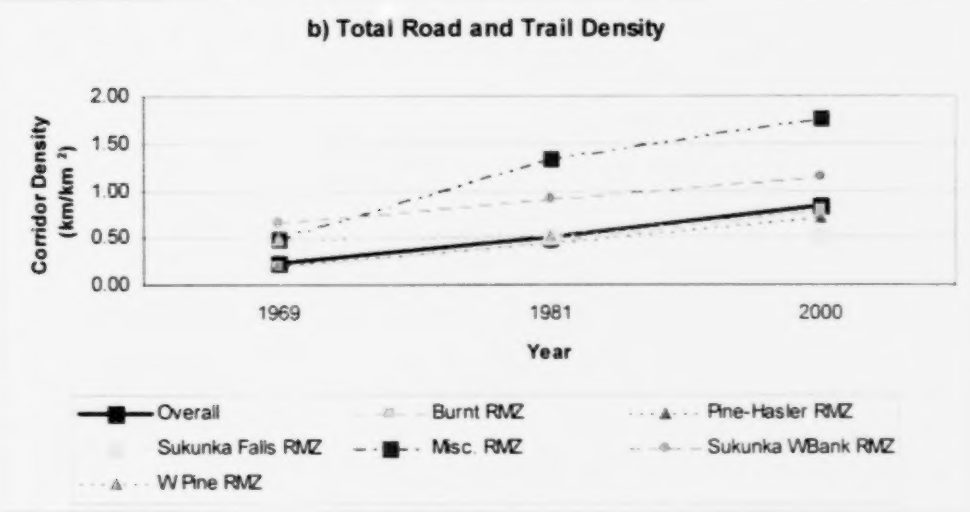
* Data are from the late 1990s

In 1969, road and truck trail access density was Very Low over 82% of the Sukunka study area, and large areas had little or no access. About 92% of the region had Moderate or lower access density. Highest road and trail density occurred in the Sukunka Falls, Miscellaneous, Sukunka River West Bank and the West Pine River RMZs (Appendix A), with average access density values of 0.52, 0.49, 0.66, and 0.49 km/km^2, respectively. All subwatersheds had Very Low or Low road density.

Road density had increased over 20% of the study area by 1981, but most of the Sukunka area was still classified as Moderate or lower. The largest increases occurred in the Miscellaneous RMZ and the Highhat River, Pine River, Hasler Creek, and Rocky Creek subwatersheds. The Burnt River subwatershed was still unentered.

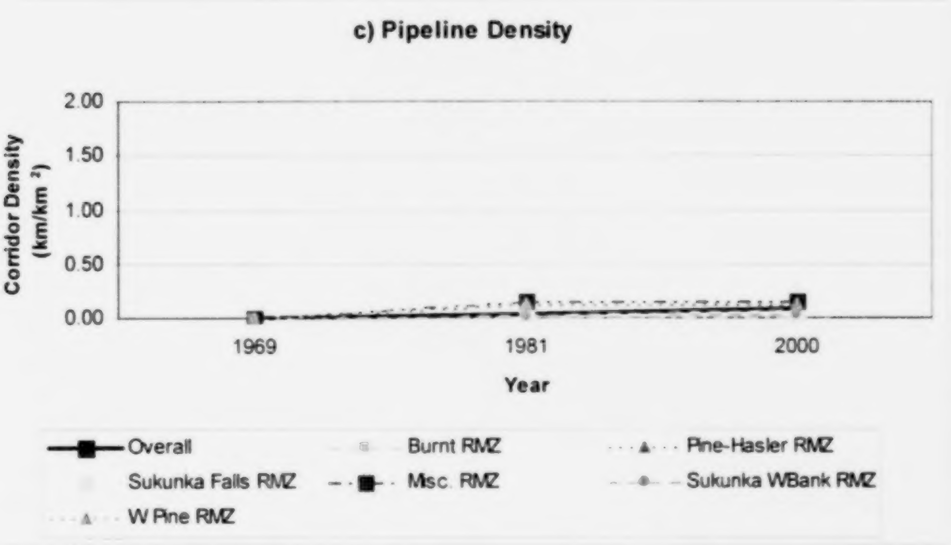


a) Truck Trail Density



b) Total Road and Trail Density

Figure 6. Access density trends in Sukunka study area RMZs.



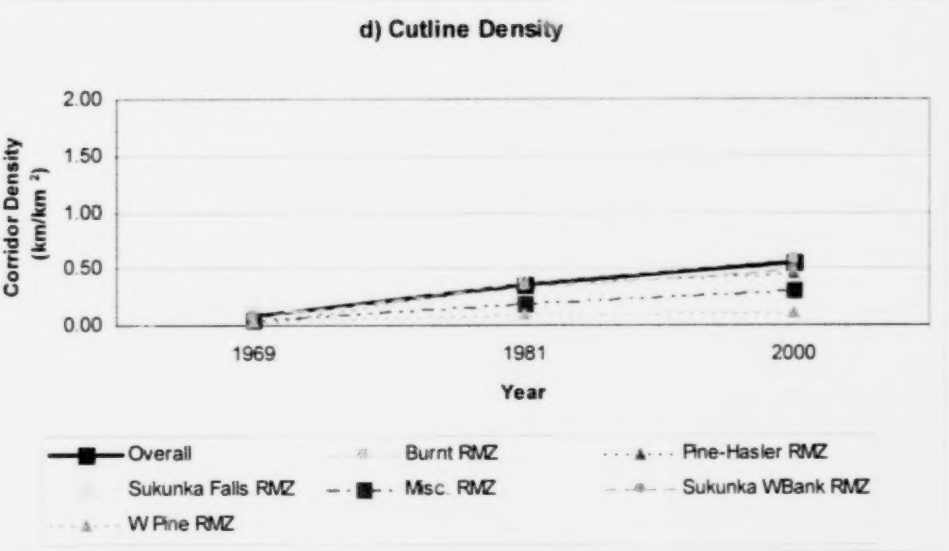
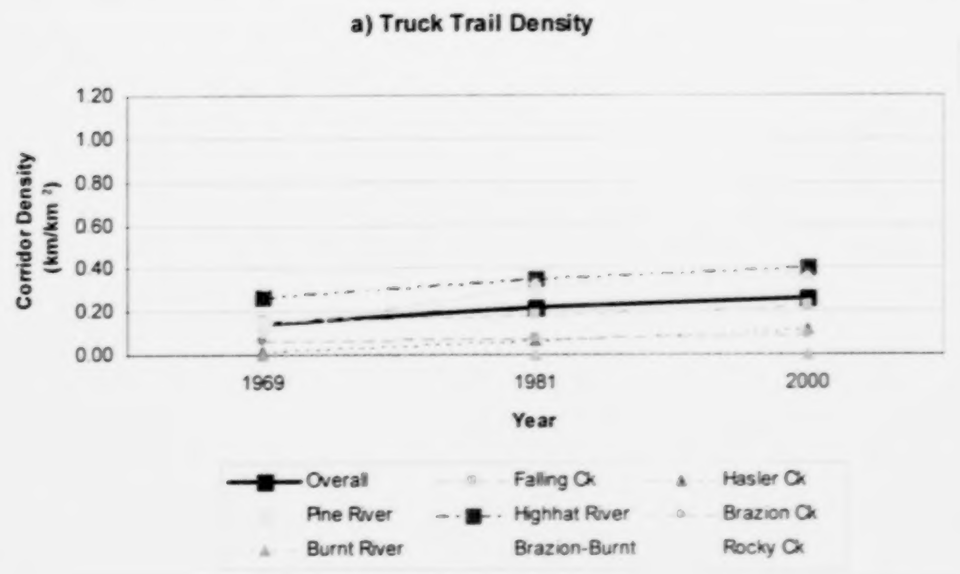


Figure 6. Access density trends in Sukunka study area RMZs (cont'd.).



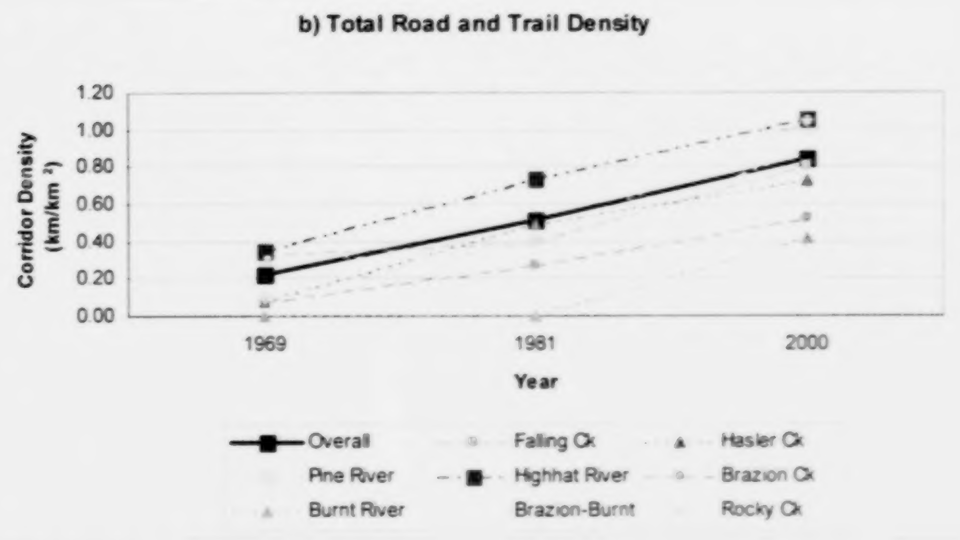
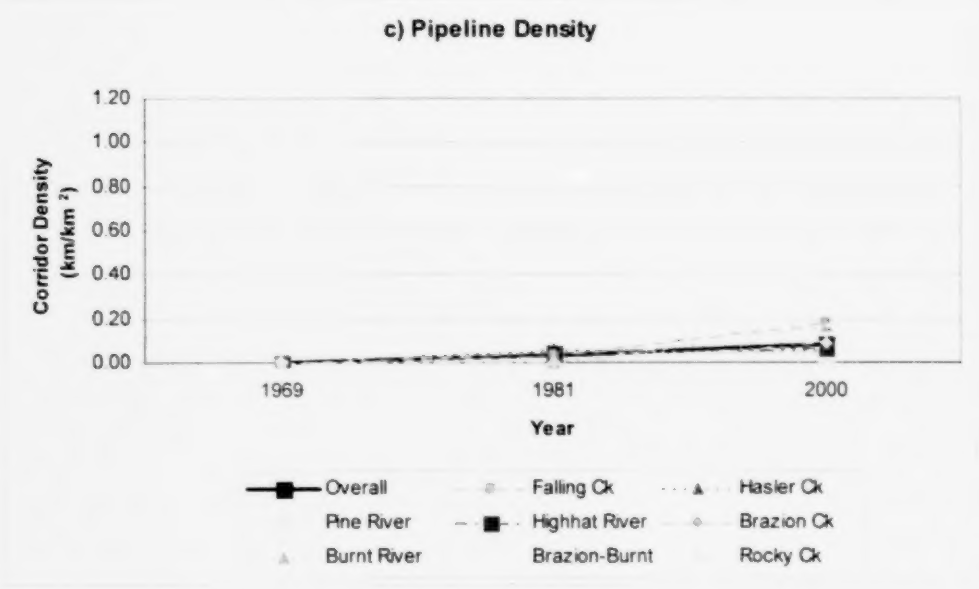


Figure 7. Access density trends in Sukunka study area subwatersheds.



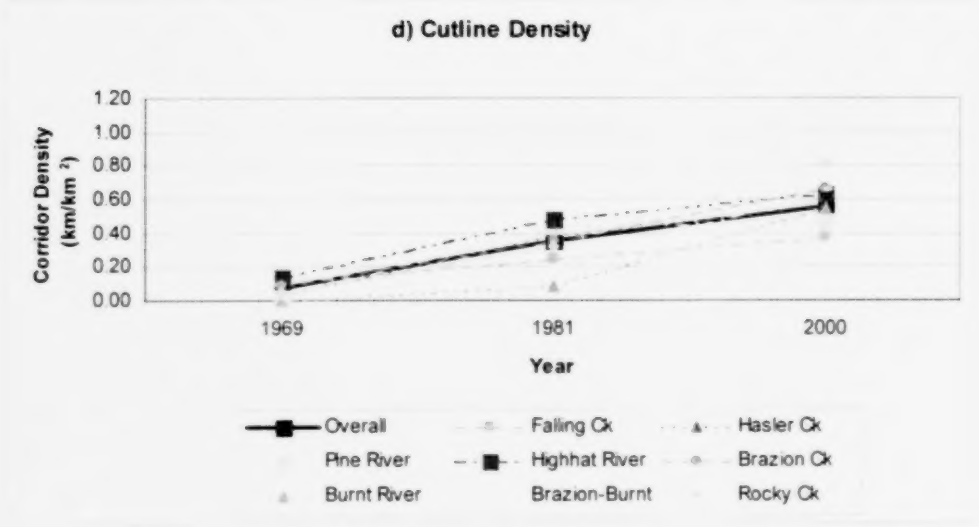


Figure 7. Access density trends in Sukunka study area subwatersheds (cont'd).

Moderate or lower average road and truck trail density still occurs on almost 70% of the Sukunka study area. Areas with little or no road access comprise about half the area; much of this is within the Burnt River subwatershed. Highest average road and trail density is present in the Miscellaneous and Sukunka River West Bank RMZs; all subwatersheds have Moderate road density (Figures 6 and 7; Appendix A).

BCF and BCE (1995b) identified the following aquatic hazard levels for road density:

Low: 0 to 0.9 km/km^2

Medium: >0.9 to 1.72 km/km^2

High: >1.72 km/km^2

Using these criteria, the overall aquatic hazard rating in 1969 was Low in all subwatersheds; less than 8% of the study area had a Medium Hazard rating. By the early 1980s, the Highhat River and Pine River subwatersheds had a Medium aquatic hazard but overall hazard level was Low elsewhere. At present, only the Brazion Creek and Burnt River subwatersheds retain a Low aquatic hazard and the rest have a Medium hazard rating (Appendix A).

Watershed road densities greater than 2.5 km/km^2 increased sediment yield and affected downstream spawning habitat in a forested coastal watershed in the Pacific Northwest (Cederholm et al. 1981). In 1969, about 2% of the Sukunka area exceeded this threshold. Road and trail densities exceeded 2.5 km/km^2 over 5% of the area in 1981, and currently exceed this threshold over 9% of the study area. At the local scale, no subwatersheds are close to this road density threshold, and the highest road density values exist in the Highhat River, Rocky Creek (each 1.05 km/km^2) and Pine River (1.02 km/km^2) watersheds (Figure 7).

3.2.4.4 Species-Specific Road Density Thresholds

Road densities greater than 0.6 km/km^2 may affect habitat usage by wolves and elk, although these effects can be mitigated by the presence of visual barriers and adjacent unroaded areas (Lyon 1983,1984; Thiel 1985; Jensen et al. 1986; Edge and Marcum 1991; Mech 1989; Rowland et al. 2000). Areas selected by grizzly bears in northern Montana and southeast British Columbia had average road densities of 0.6 to 0.68 km/km^2 (Mace et al. 1996; McLellan and Hovey 2001). Road densities greater than 1.2 km/km^2 may affect habitat usage by grizzly bear (Mace and Manley 1993) and areas with road densities greater than 6 km/km^2 do not appear to support grizzly bears (Mace et al. 1996). Bull trout populations were seven times more likely to be strong in subwatersheds with road densities less than 1.55 km/km^2 in the Columbia and Klamath river basins in the Pacific Northwest (Rieman et al. 1997).

Figure 8 presents current combined road and truck trail density in the Sukunka Case Study area in comparison to 0.6 and 1.2 km/km^2 thresholds. The 0.6 km/km^2 road density threshold was exceeded on nearly 12% of the Sukunka study area in 1969 (including the Sukunka River West Bank RMZ), and over 25% of the area in 1970 (including the Sukunka River West Bank and Miscellaneous RMZs). Road density currently exceeds 0.6 km/km^2 on approximately 50% of the Sukunka study area (Figure 8). This threshold is exceeded in each RMZ except Sukunka Falls RMZ and across all subwatersheds except Brazion Creek (Appendix A), which suggests that habitat usage by sensitive species has been affected throughout the Case Study area.

The 1.2 km/km^2 road and trail density threshold was exceeded on less than 8% of the Sukunka study area in 1969 and 16% of the area in 1981. At the local scale, the road density threshold was exceeded in the Current road density exceeds 1.2 km/km^2 on approximately 28% of the Sukunka study area, and grizzly bears may avoid these highly fragmented parts of the Sukunka study area on a seasonal, daily, or continuous basis.

The 6 km/km^2 road density threshold was exceeded on less than 0.1% of the Sukunka study area in 1969, and 0.3% of the area in 1981. Road density currently exceeds 6 km/km^2 on approximately 0.5% of the Sukunka study area, which suggests that probability of grizzly bear persistence is not greatly affected by roads and trails in the overall Sukunka Case Study area.

In 1969, almost 95% of the Sukunka study area was within the 1.55 km/km^2 threshold reported for bull trout persistence. By 1981, about 88% of the area had road and truck trail density less than this value. At present, almost 78% of the Sukunka study area remains below this observed threshold. None of the subwatersheds exceed this threshold, which is consistent with the wide distribution of bull trout in the Sukunka area.

3.2.4.5 Cleared/Disturbed Area

Overall clearing trends for the Sukunka Case Study area are summarized by RMZ in Figure 9 and by subwatershed in Figure 10 based on data provided in Appendix A.

In 1969, less than 1% of the study area was cleared for combined industrial, agricultural, residential, and infrastructure development; converted area was greatest in the Miscellaneous and West Pine RMZs. By 1981 total cleared and disturbed areas had doubled in size to almost 2.5% of the area.

Currently, about 6.5% of the overall Sukunka study area has been directly affected by clearing for mining, forestry, petroleum development and utility corridors. The areas most affected are the Miscellaneous RMZ and the Rocky Creek and Pine River subwatersheds.

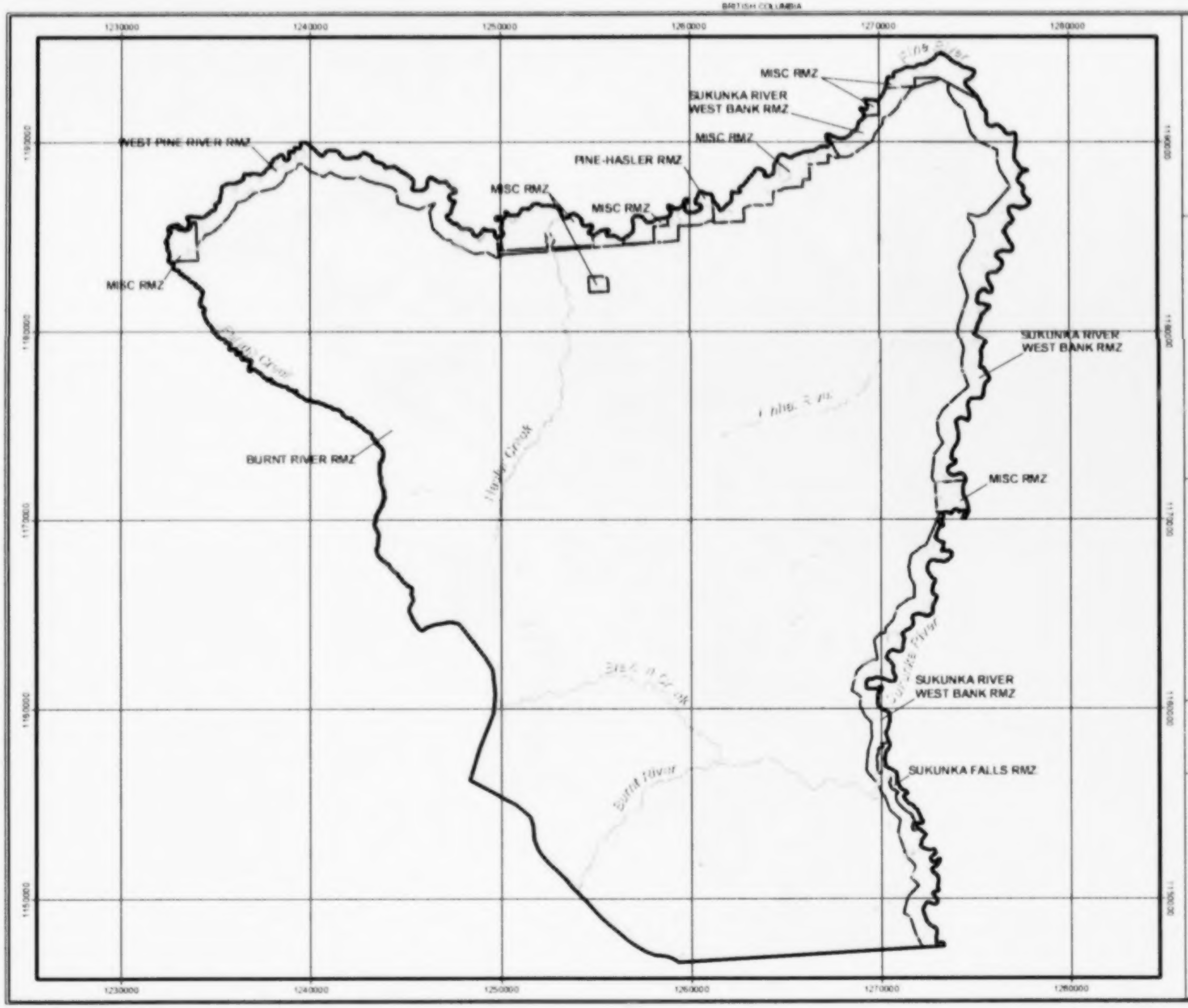


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Figure 8

Current Combined Road and Truck Trail Density in the Sukunka Case Study Area

LEGEND

- Study Area
- RMZ Boundary
- Hydrography
- Albers Coordinate Grid

Access Density

- <0.60 km / km²
- 0.60 - 1.20 km / km²
- >1.20 km / km²

Map Scale 1 : 200 000

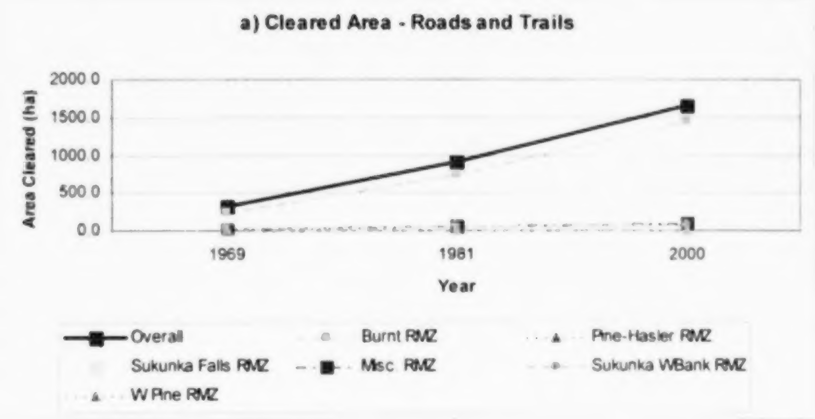
MAP INFORMATION

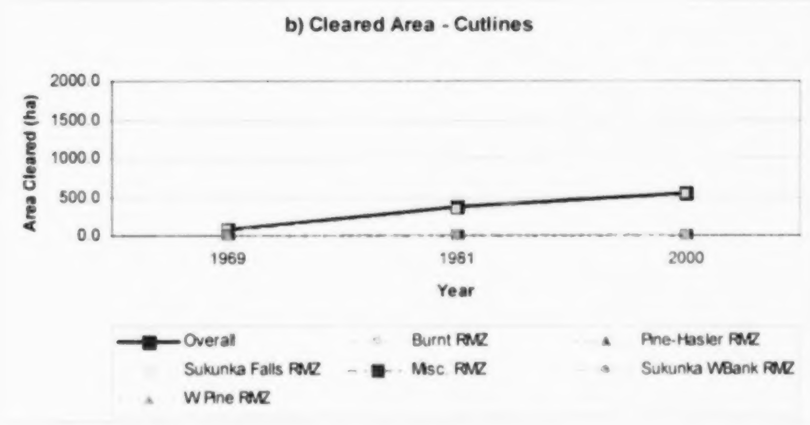
Sources:
RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Access Density Grid created by GAIA Consultants Inc. as part of the CEA analysis performed using TRIM data

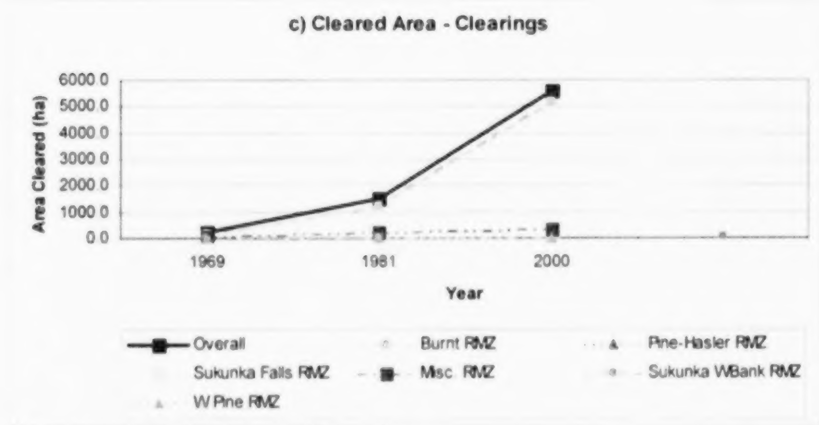
Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

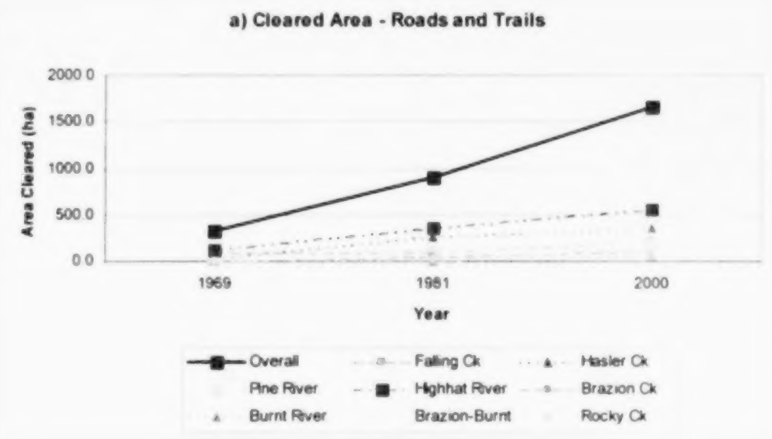

a) Cleared Area - Roads and Trails

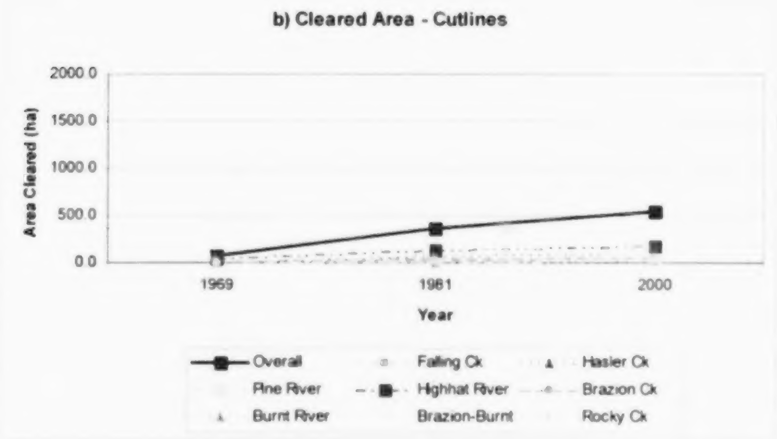

b) Cleared Area - Cutlines

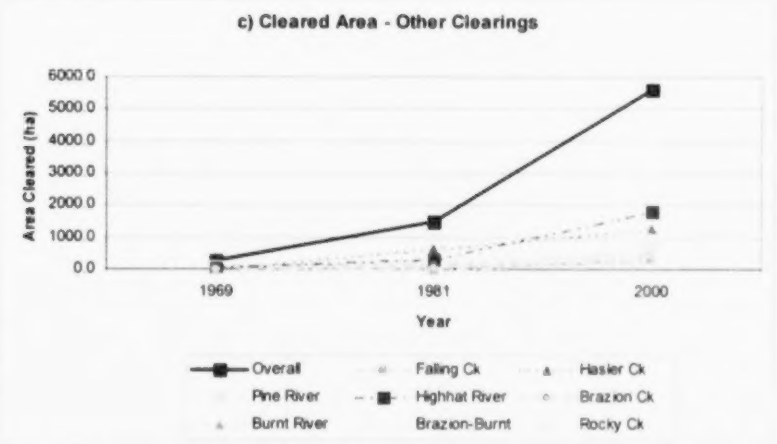

c) Cleared Area - Clearings

Note change in scale on y axis of Chart C.

Figure 9. Trends in forest clearing in Sukunka study area RMZs.







Note change in scale on y axis of Chart C.

Figure 10. Trends in forest clearing in Sukunka study area subwatersheds.

Generalized clearing thresholds have been applied for landscape-level evaluations of cumulative effects on terrestrial habitat; species-specific evaluations usually consider the quality of available habitat as well.

Theoretical models suggest that habitat specialists may be affected when available habitat occupies less than 40% of the landscape, whereas habitat generalists may be affected when suitable habitat occupies less than 20% to 35% of the landscape (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995). Marten home ranges in black spruce forest in Quebec usually contained more than 40 to 50% uncut forest (Potvin et al. 2000). Maintenance of more than 50% to 75% forest cover in areas greater than 9 to 10 km^2 (Hargis et al. 1999; Potvin et al. 2000) has been recommended to protect marten. At a landscape scale, current clearing in the Sukunka study area is well within theoretical criteria for habitat specialists.

Available literature indicates that detectable effects on streamflow occur when more than 20% of a watershed is cleared in less than 10 years (McGurk and Fong 1995). Risk of cumulative effects is elevated where cleared area (expressed as equivalent clearcut area) exceeds 18%, and greatly elevated where cleared area exceeds 36% (BCF and BCE 1995b). Cleared area in the overall Sukunka study area and subwatersheds has not exceeded these thresholds.

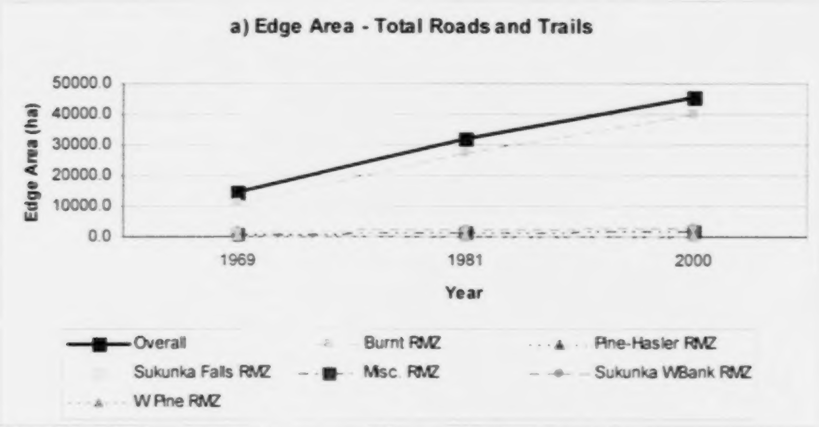
Sediment accumulation increases when road area is greater than 2.5% of basin area (Cederholm et al. 1981). Combined road and truck trail areas do not exceed this observed threshold in any subwatersheds in the Sukunka Case Study area (Appendix A), which suggests that sediment yield has not been affected in this area.

3.2.4.6 Edge Area

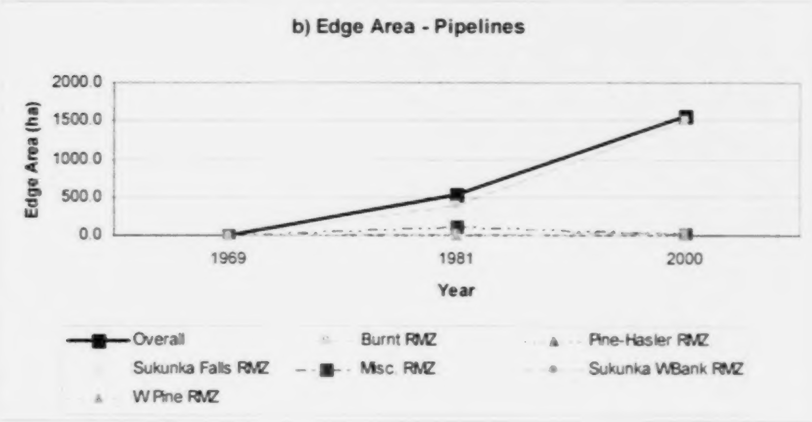
Trends in combined edge areas adjacent to low and high use features are summarized by RMZ in Figure 11 and by subwatershed in Figure 12. Complete data are provided in Appendix A.

Total edge area currently calculated to represent about 41% of the overall Sukunka study area having risen from 13% in 1969 and 29% in 1981. Edge area has increased gradually but consistently in most RMZs and subwatersheds, although most edge area in the major river valleys was created prior to 1981. On a subwatershed basis, edge area is highest in the Brazion-Burnt River and Rocky Creek drainages, and most edge area was created between 1981 and present.

Theoretical models suggest that >40-50% edge area represents a threshold for ecological effects (Wilcove et al. 1986; Lee and Gosselink 1988; Laurance and Yensen 1991; With and Crist 1995). This threshold is currently exceeded in the Miscellaneous, West Pine River, Sukunka River West Bank, and West Pine River RMZs. Edge area in the Sukunka Falls and Burnt River RMZs are at or near the lower end of this threshold. In these areas, habitat effectiveness for sensitive species has likely been compromised.



Note the scale change on y axis between Chart A and Charts B and C



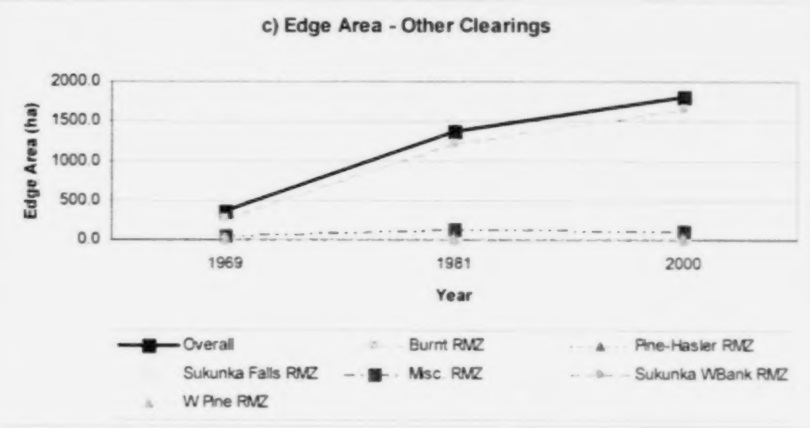
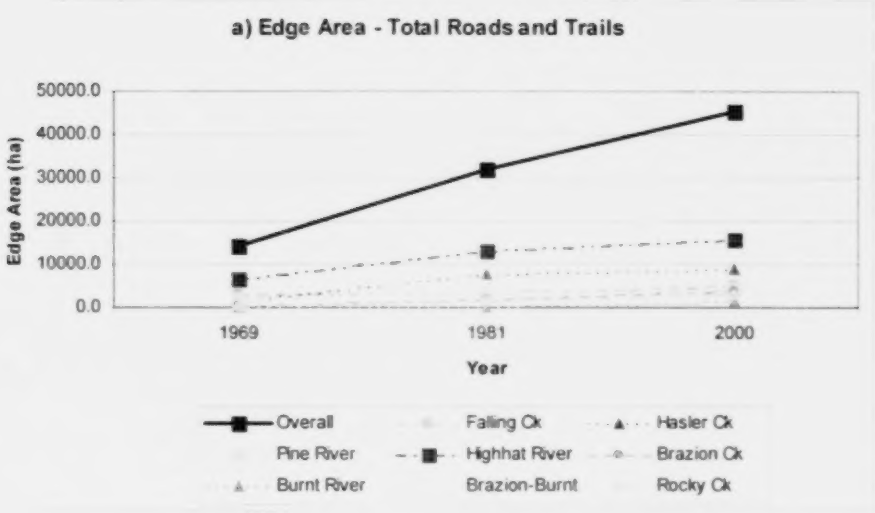


Figure 11. Trends in edge area in Sukunka study area by RMZ.



Note the change in scale on y axis between Charts A and B.

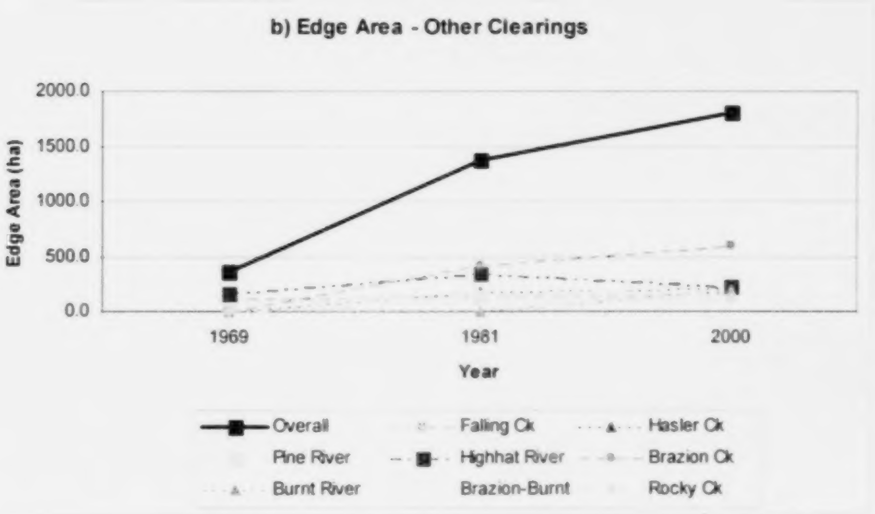


Figure 12. Trends in edge area in Sukunka study area by subwatershed.

3.2.4.7 Core Area

Trends in core area within the Sukunka Case Study area are summarized by RMZ in Figure 13 and subwatershed in Figure 14.

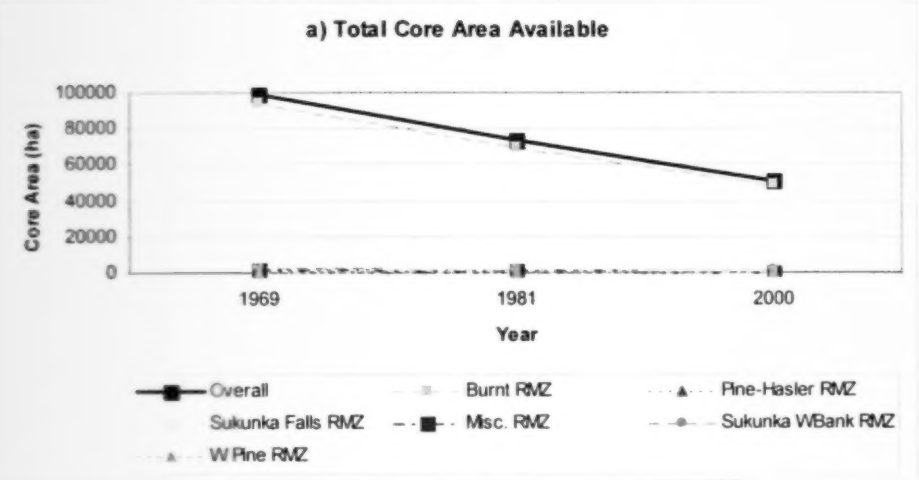
Core areas greater than 500 m from possible high use human features are currently present on about 42% of the Sukunka study area. The most rapid fragmentation of core areas occurred between 1969 and 1981. Ongoing fragmentation has reduced average core area size from 1,400 ha to about 605 ha since 1981. Based on median values, most core areas are currently less than 30 ha in size. Residual core area is highest in the Pine-Hasler RMZ and the recently entered Burnt River subwatershed. Relatively undisturbed areas are least abundant in the Miscellaneous and West Pine RMZs and the Rocky Creek and Burnt-Brazion subwatersheds (Appendix A).

Core area sizes can be compared with minimum home range size to assess their suitability for specific species. Black-throated green warbler, a representative interior forest songbird of concern found in the study area, appear to require a minimum of 40 ha of suitable habitat (Hannon 1992). Marten are a representative furbearer of concern that appear to require more than 100-200 ha of suitable habitat (Buskirk and Ruggiero 1994). Female grizzly bears appear to require a portion of their home range that is secure from high use human activities, and the concept of core security areas has been used for assessment and management of cumulative effects on this species. Core security areas are considered to be that portion of home range that corresponds to a 24 to 48 feeding bout of an adult female grizzly bear (Mattson 1993; Mace et al. 1996). Minimum areas of 450 ha to 1,010 ha have been used in assessments in western Canada and 60% of available habitat should be in core areas (Gibeau et al. 1996; CRC 1999; Kansas and Collister 1999; Gibeau 2000).

In 1969, core areas consisted of a few very large patches and several small patches. At this time, core area availability and core area size were likely not limiting warblers, marten, and grizzly bear, assuming suitable habitat existed. By the late 1990's, 45% of the 85 core areas were large enough to support warblers, 25% to 40% were large enough for marten, and 10% to 17% were large enough to support a female grizzly, although only the Burnt River watershed retained more than 60% core area.

3.2.4.8 Stream Crossing Index

Riparian features (clearings and roads) and stream crossings used for watershed analyses in the Sukunka study area are depicted in Figure 15. Trends in numbers of stream crossings in the Sukunka study area are summarized by RMZ in Figure 16 and subwatershed in Figure 17.



Note the 10-fold change in scale on y axis between Charts A and B.

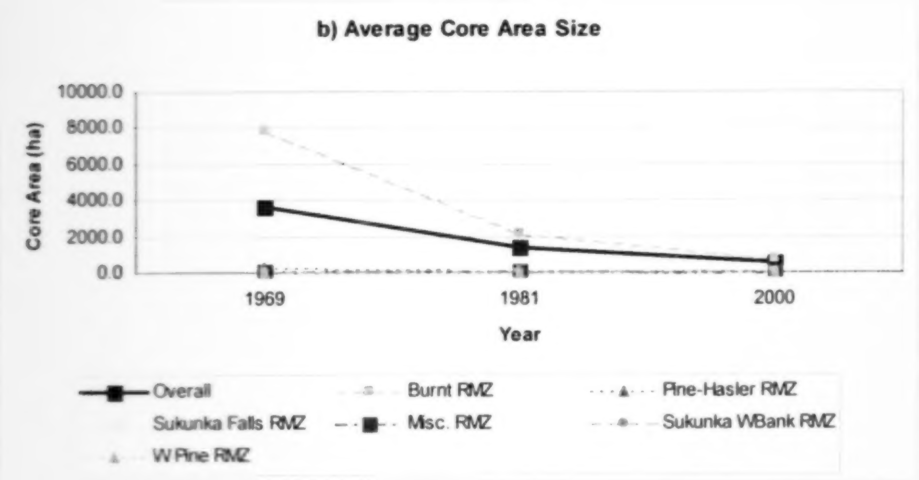
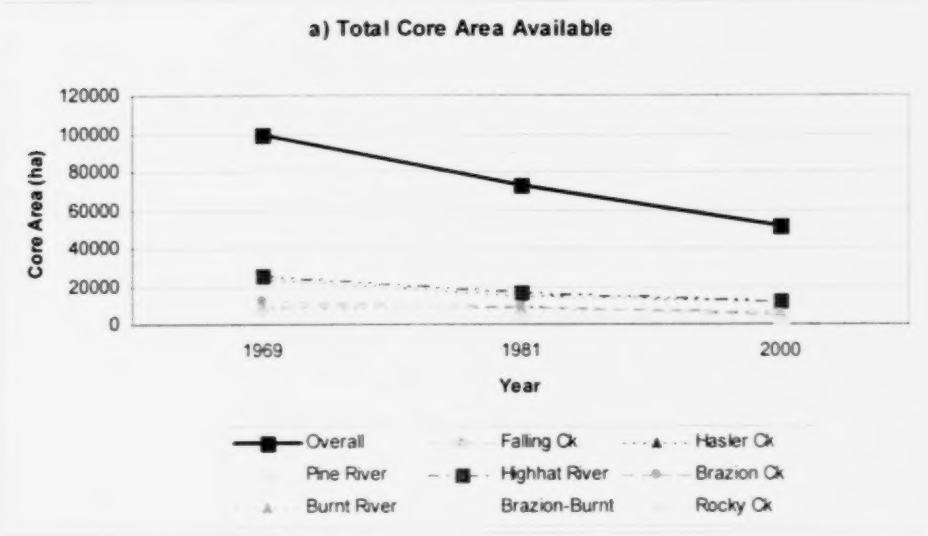


Figure 13. Trends in available core area in Sukunka study area RMZs.



Note the 10-fold change in scale on y axis between Charts A and B.

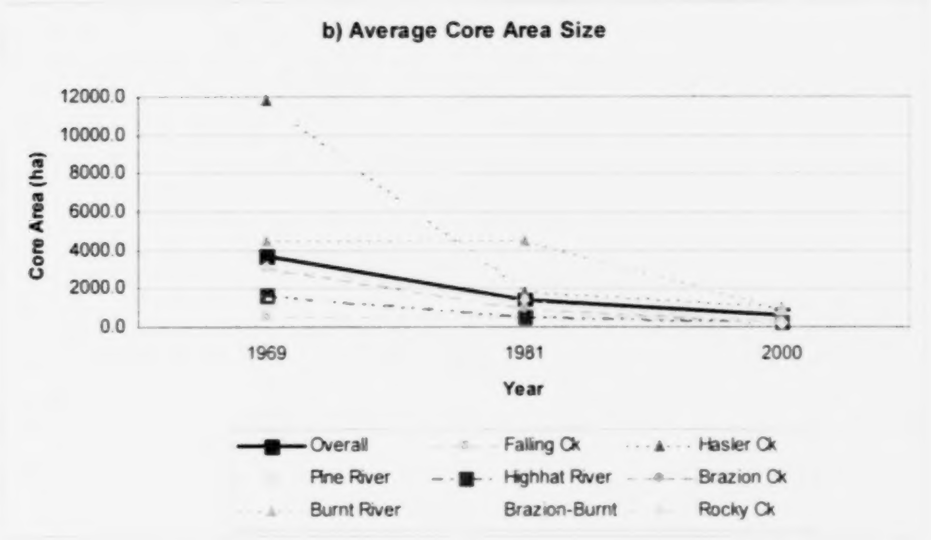


Figure 14. Trends in available core area in Sukunka study area subwatersheds.

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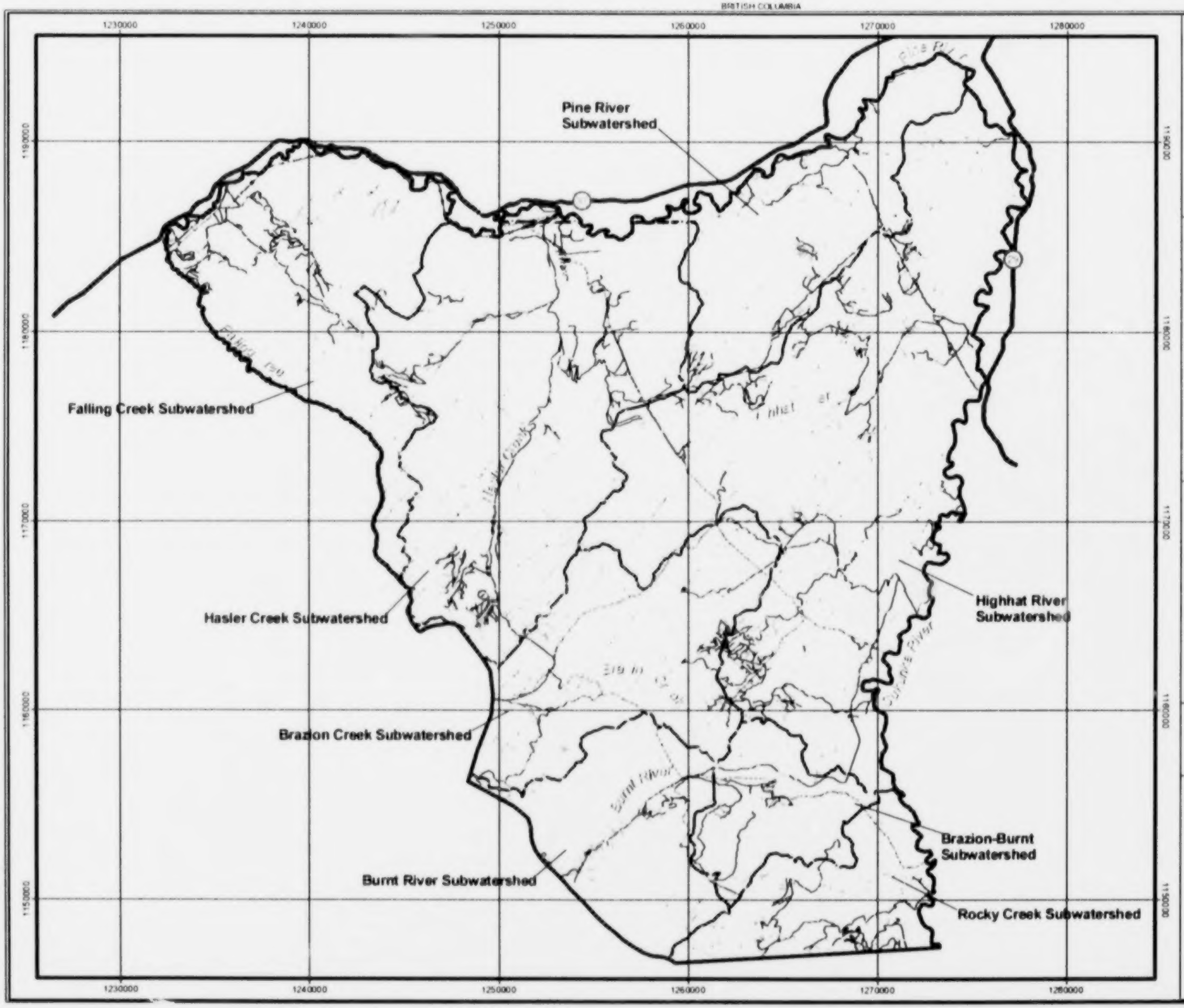


OGC

Figure 15

Riparian Features and Stream Crossings in the Sukunka Case Study Area

LEGEND

- ▭ Study Area
- Riparian Area
- ▨ Riparian Disturbance
- ▭ Subwatershed
- Hydrography
- Primary Highway
- Secondary Road
- Rail Line
- Pipeline
- Stream Crossing
- Albers Coordinate Grid

N E S W

0 1 2 4 6 8 Km

Map Scale 1 : 200 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. Hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from a DEM. Primary Highway taken from ESRI maps and data. Stream Crossings, Riparian Area, and Disturbances created by GAIA Consultants Inc. based on TRIM data.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

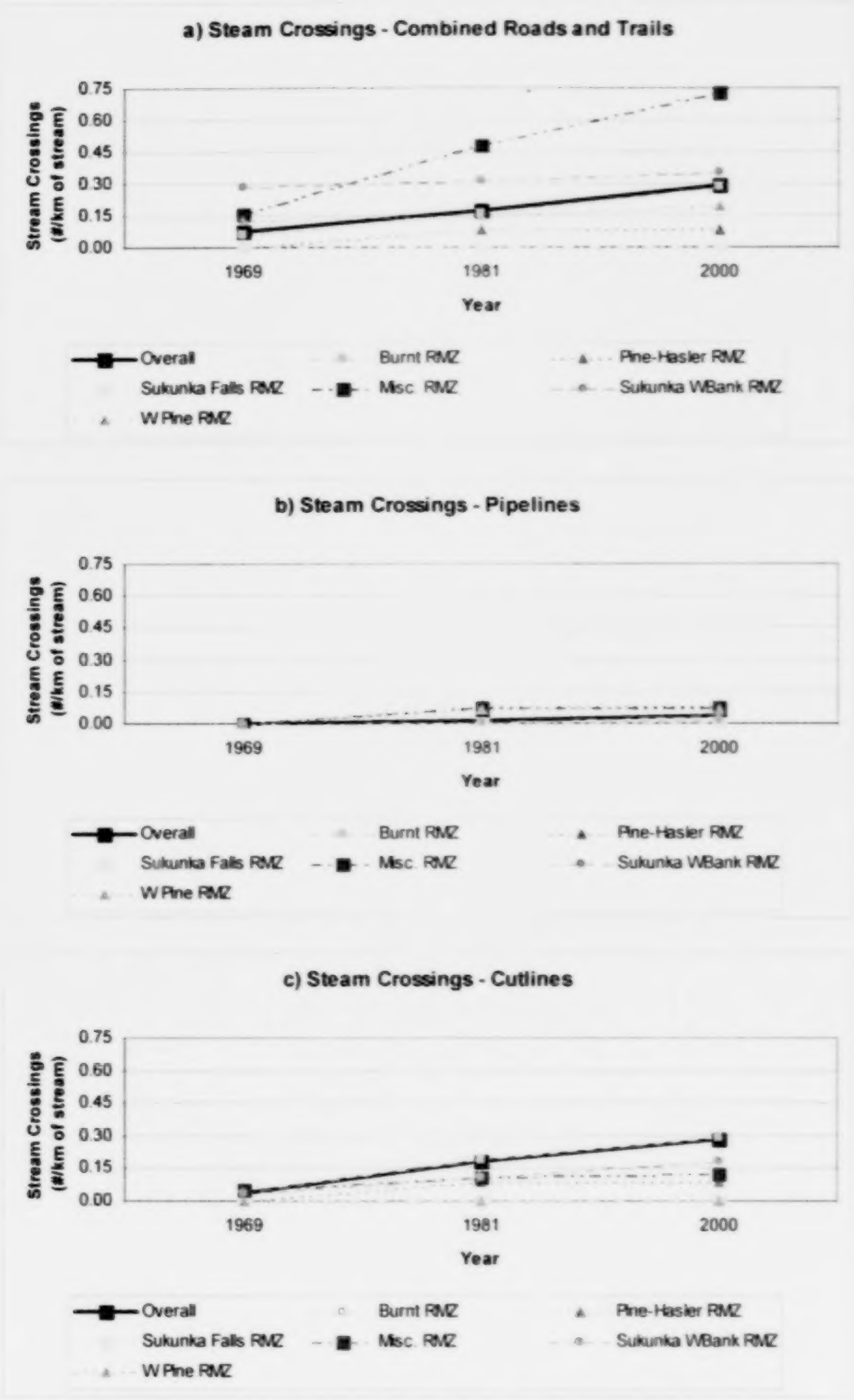


Figure 16. Stream crossing trends in Sukunka study area RMZs.

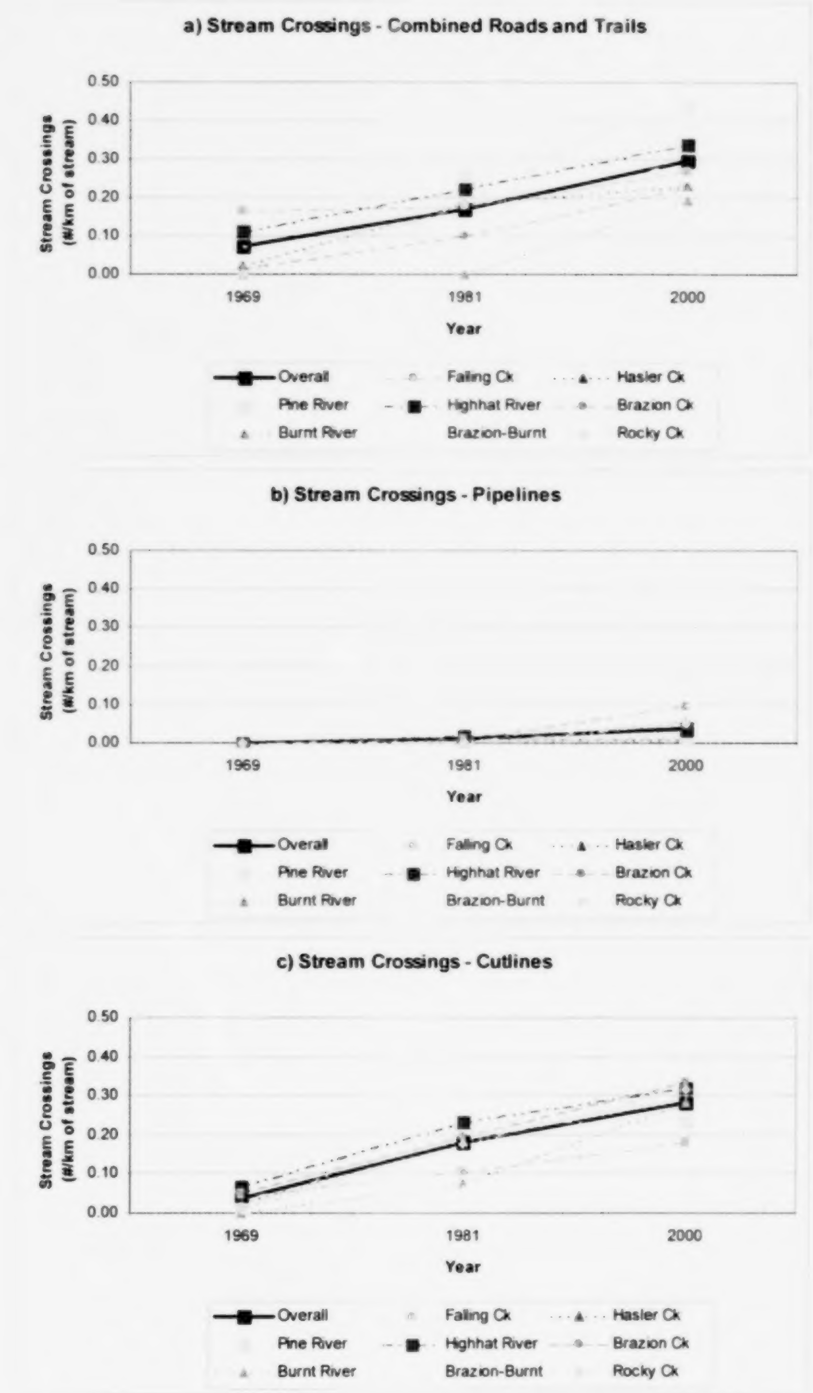


Figure 17. Stream crossing trends in Sukunka study area subwatersheds.

Streams in the Sukunka study area are currently crossed on average once every 4.5 km by primary and secondary roads, once every 12.5 km by truck trails, once every 20 km by utility corridors, and once every 3.6 km by cutlines. Total stream crossings are lowest in the Falling Creek, Burnt River, and Hasler Creek subwatersheds (0.52 to 0.53 crossings per km each), highest in the Rocky Creek subwatershed (0.85 crossings/km), and intermediate (0.57 to 0.67 crossings/km) in the remaining subwatersheds. Cutlines are generally the most frequent type of crossing feature in all watersheds, although secondary roads comprise almost one-third or more of the stream crossings in every subwatershed (Figures 15 and 16; Appendix A).

Expressed in terms of crossing frequency, stream crossings in the overall Sukunka study area were infrequent in 1969, with one crossing every 8.3 km. By 1981, average stream crossing density in the overall Sukunka study area had increased to one crossing every 2.7 km. At present, each stream in the study area is crossed by a linear corridor every 1.6 km, on average.

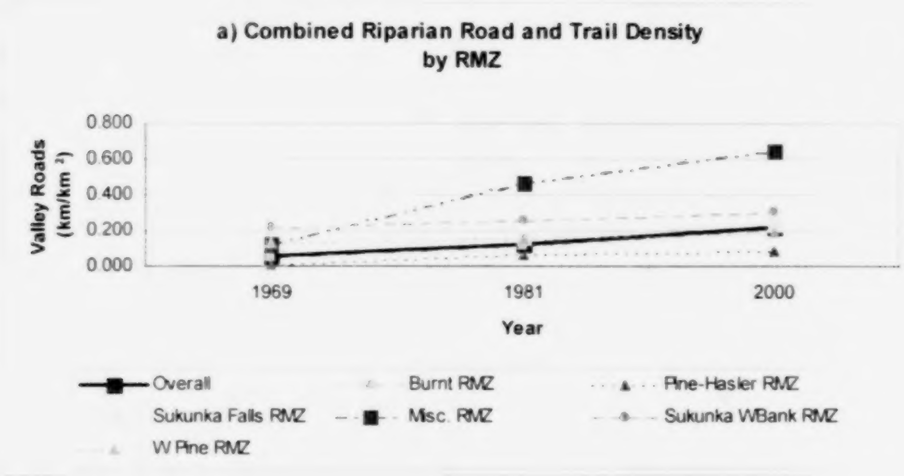
Consistent increases in stream crossing frequency have occurred in the Sukunka study area since 1969; these have mirrored general development patterns. Road and trail crossings occur most frequently in the Miscellaneous and Sukunka West Bank RMZs and the Rocky Creek and Pine River subwatersheds (Figures 15 and 16; Appendix A).

Although there are no established threshold criteria for stream crossing frequency, stream crossing numbers in the Sukunka study area are lower than other areas of the eastern slopes in Alberta and British Columbia (Alliance 1997; Salmo 1999, 2000, unpub. data). Based on existing road and corridor patterns, Rocky Creek and the Sukunka River are relatively accessible to fishermen and have moderate numbers of potential sediment sources and barriers to fish movements associated with corridor crossings. Other watercourses have more limited accessibility and low to moderate numbers of potential sediment sources.

3.2.4.9 Riparian Roads

Trends in the number of roads and trails constructed within 100 m of waterbodies in the Sukunka study area are summarized by RMZ and subwatershed in Figure 18. In the absence of site-specific watershed surveys of the Sukunka study area and data from other similar areas, hazard levels for valley roads were assigned from original IWAP rating scores (BCF and BCE 1995b).

Low:	0 to 0.12 km/km^2
Medium:	>0.12 to 0.25 km/km^2
High:	>0.25 km/km^2



Note the 10-fold change in scale on the y axis between Charts A and B.

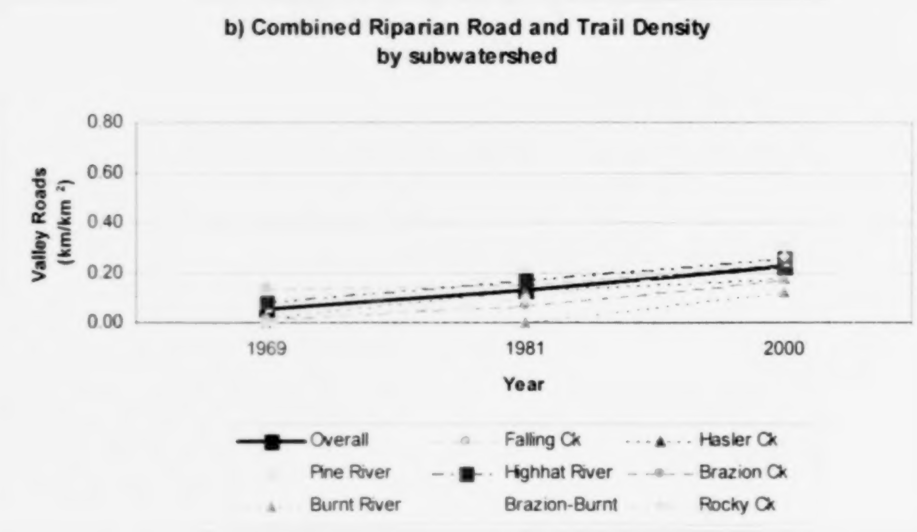


Figure 18. Riparian roads in Sukunka study area RMZs and subwatersheds.

In 1969, the overall Sukunka study area had a Low aquatic hazard rating from valley roads and trails. By 1981, the aquatic hazard rating had increased to Medium in all subwatersheds except the Burnt and Brazion-Burnt rivers. The overall Sukunka study area currently has a Medium aquatic hazard rating due to valley roads and truck trails. Subwatersheds with a High aquatic hazard rating include Pine River, Rocky Creek, and Highhat River. The remaining five subwatersheds also have a Medium aquatic hazard rating (Figure 18, Appendix A).

3.2.4.10 Cleared Riparian Area

Trends in the amount of riparian area cleared the number of roads and trails constructed within 100 m of waterbodies in the Sukunka study area are summarized by RMZ in Figure 19 and subwatershed in Figure 20. In the absence of data site-specific watershed surveys of the Sukunka study area and data from other similar areas, hazard levels for riparian clearing were assigned from original IWAP rating scores (BCFS and BCE 1995b):

Low: 0 to 9%

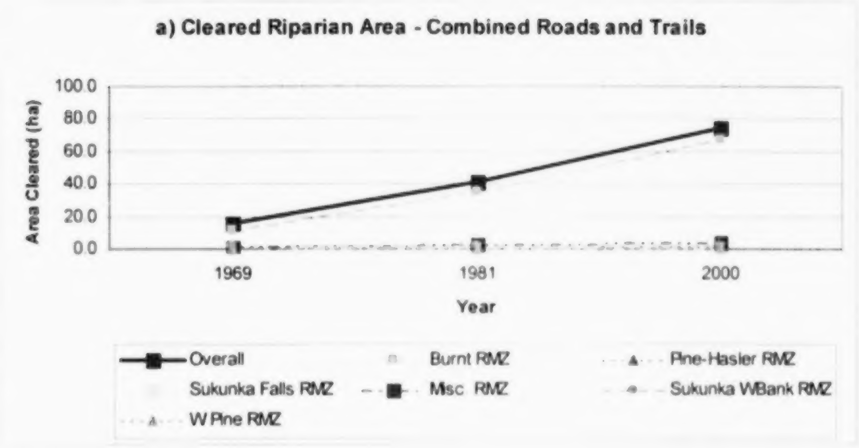
Medium: >9 to 18%

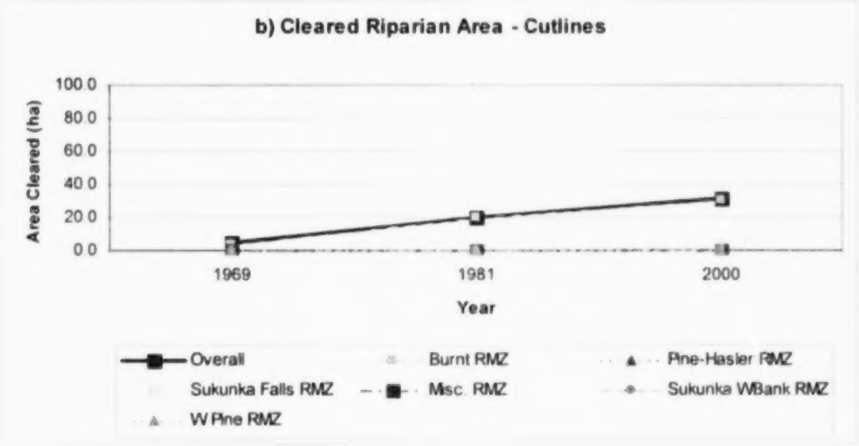
High: >18%

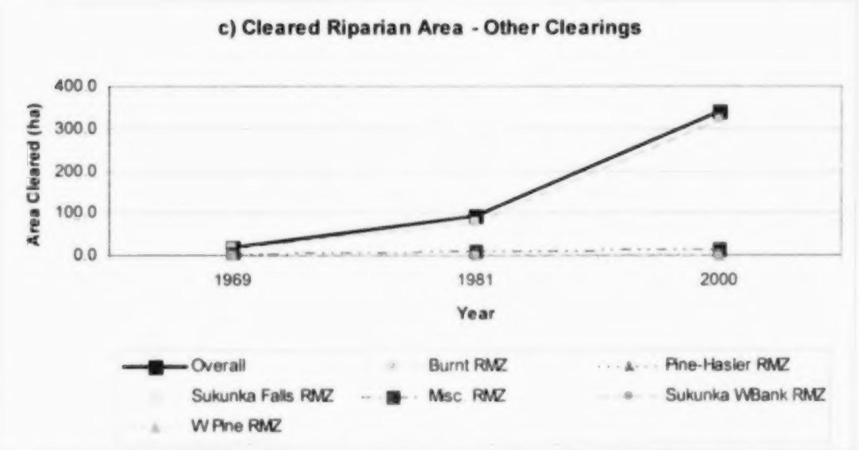
In 1969, riparian area cleared in the Sukunka Study Area overall, and all major subwatersheds represented a Low aquatic hazard based on the IWAP rating scores. The Falling Creek subwatershed contained the highest percentage (0.17%) of riparian area cleared, more than half of which was due to cutblocks and clearings. The Rocky Creek subwatershed also had very low levels of riparian area clearing, and the Burnt River subwatershed was unentered.

The aquatic hazard remained Low in the overall Sukunka study area and all major subwatersheds in 1981. Over half the riparian clearing in the Sukunka Case Study area was a result of cutblocks and clearings; 25% was attributable to secondary roads and truck trails. The Hasler Creek and Falling Creek subwatersheds were most affected by riparian clearing, but hazard rating was still Low.

The aquatic hazard rating remained Low across the overall Sukunka study area, and each major subwatershed through the late 1990's. Most riparian clearing in this area has resulted from clearing for forest harvest and agricultural conversion. The lowest levels of riparian clearing have occurred in the Brazion-Burnt watershed.

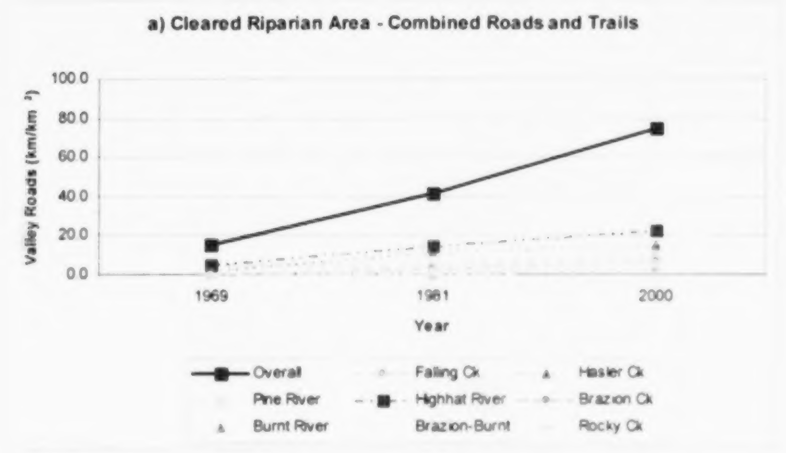

a) Cleared Riparian Area - Combined Roads and Trails

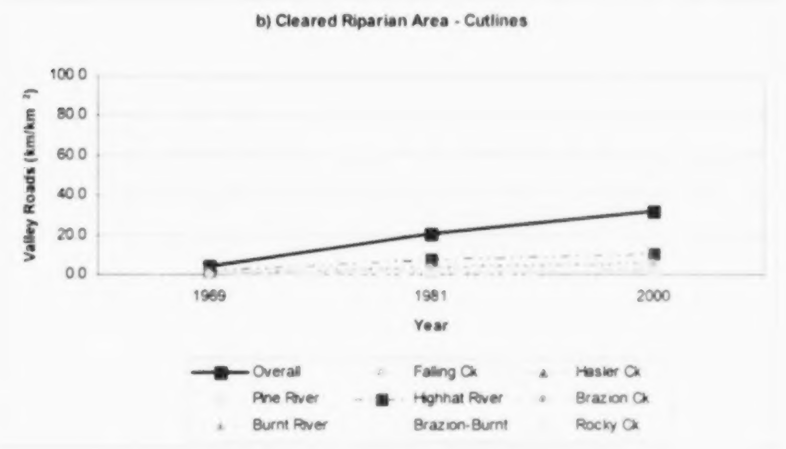

b) Cleared Riparian Area - Cutlines

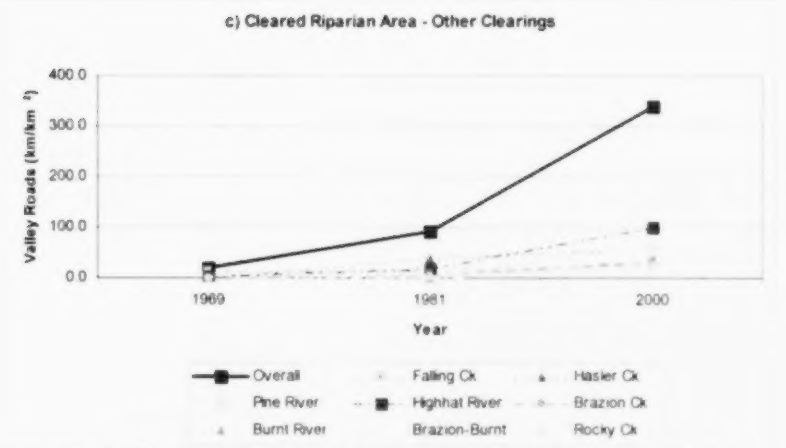

c) Cleared Riparian Area - Other Clearings

Note the 4-fold change in scale on the y axis between Charts A and B, and Chart C.

Figure 19. Trends in riparian clearing in Sukunka study area RMZs.


a) Cleared Riparian Area - Combined Roads and Trails


b) Cleared Riparian Area - Cutlines


c) Cleared Riparian Area - Other Clearings

Note the 4-fold change in scale on the y axis between Charts A and B, and Chart C.

Figure 20. Trends in riparian clearing in Sukunka study area subwatersheds.

3.3 RENEWABLE RESOURCE TRENDS

Information on renewable resource availability, abundance and distribution were generated from a review of available files and interviews with representatives of MWLAP and MSRM in Fort St. John. Hunter and trapper harvest data were obtained to document historical trends in harvest and inferred abundance.

3.3.1 Natural Range of Variability

Naturally caused changes in fish and wildlife populations in the Sukunka Case Study area occur as a result of natural disturbances such as fire, disease, parasites, pests, floods, droughts, predation, and severe weather conditions. Fire and insects are the most important natural disturbances affecting the boreal forest. Floods, droughts, accelerated erosion, and channel barriers are the most important disturbances affecting aquatic habitat (Meehan 1991; Young 1994; Frissell and Bayles 1996; Andison 1999, 2000).

The natural disturbance regime is determined by long-term climatic and short-term weather as well as physiographic watershed characteristics. The frequency and magnitude of disturbance events affect the composition, productivity, and successional state of terrestrial and riparian vegetation as well as the connectedness and productivity of waterbodies (Ward 1989; Regier and Meisner 1990). This causes the distribution, pattern, and abundance (mosaic) of habitat to change in both time and space.

Fish and wildlife assemblages in northeast British Columbia have adapted to these natural disturbances, but individual species differ in their inherent ability to absorb disturbance and still persist as viable populations over time. At any point in time, species abundance and distribution reflects habitat availability and quality as well as biological factors such as immigration, emigration, and juvenile and adult mortality that are dictated by weather, predation rate, and life history patterns.

Observed variability in abundance appears to increase with the length of time over which it is monitored or calculated, and data sets of 50 years or more are required to understand natural range of variability (Pimm and Redfearn 1988; Thomas 1990).

Winter snow depth is a critical factor affecting wildlife populations in the Sukunka study area; Historical snow depth records for the Fort St. John airport are presented in Figure 20. Between 1971 and 2000, the long term average snow depth at this station was 31 cm, and extreme snow depth was 112 cm in 1974. Limiting snow depths are assumed to be 40 cm for deer, 50 cm for elk, and 65 cm for moose (Nietfeld et al. 1985). The 7 year period of mild winters beginning in 1984 provided very good conditions for ungulate population growth.

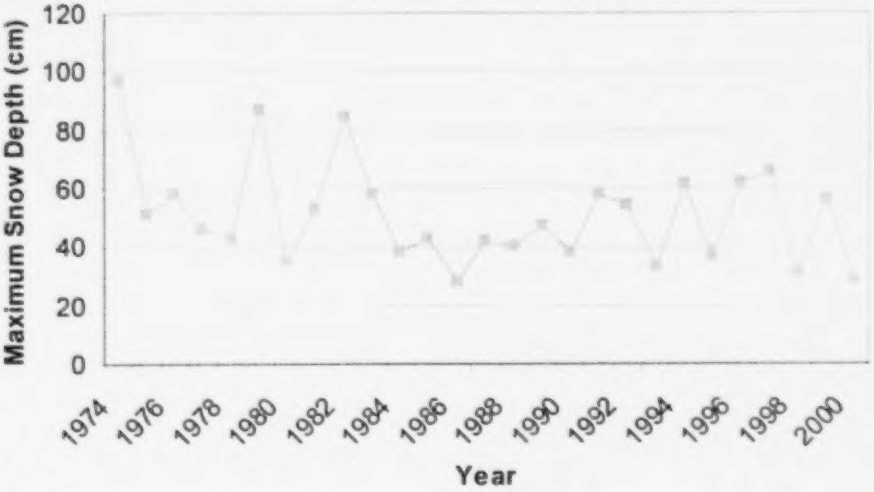


Figure 21. Reported winter snowfall at Fort St. John airport.

3.3.2 Moose (*Alces alces*)

Moose are relatively abundant in the Sukunka study area and are highly sought after by recreational and subsistence hunters (Harper 1988). Moose are a habitat generalist with moderate reproductive potential and are relatively tolerant of human disturbance. Key factors limiting moose populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk),
- natural abiotic and biotic factors (predation, tick infestations and disease, snow depth, natural succession), and
- habitat loss and alteration (clearing, fire suppression).

3.3.2.1 Habitat Availability and Suitability

Current moose habitat suitability ratings derived for the Sukunka Case Study area are summarized in Table 7 and depicted in Figure 22.

Habitat in the Sukunka area was rated as High to Low capability (Class 2 to 4) for moose by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use or seral stage.

Table 7. Current moose habitat suitability in the Sukunka study area (area classified as core in parentheses).

Analysis Unit	**Suitability Class**							
	High		**Moderate**		**Low**		**Nil**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Sukunka Overall	1,010 (320)	<1 (<1)	39,780 (14,572)	33 (12)	77,666 (36,133)	64 (30)	3,061 (385)	3 (<1)
Burnt River RMZ	658 (232)	<1 (<1)	31,477 (12,365)	29 (11)	75,077 (35,505)	68 (32)	2,817 (349)	3 (<1)
Misc RMZ	62 (<1)	2 (<1)	1,770 (129)	58 (4)	1,190 (163)	39 (5)	50 (2)	2 (<1)
Pine-Hasler RMZ	0 (0)	0 (0)	390 (195)	66 (33)	185 (137)	31 (23)	20 (3)	3 (<1)
Sukunka Falls/West Bank RMZs	273 (88)	5 (2)	4,659 (1,334)	82 (23)	611 (222)	11 (4)	150 (29)	3 (<1)
West Pine R. RMZ	17 (0)	<1 (0)	1,484 (279)	70 (13)	604 (108)	28 (5)	24 (1)	1 (<1)

Approximately 12% of the Sukunka Case Study area is currently rated as Moderate to High Suitability habitat. Habitat suitability of burned, logged, or cleared areas between 5 and 20 years old is increased for 'edge' species such as moose, deer, and elk (Westworth and Telfer 1993; Puttock et al. 1996), and the availability of young seral stages affects moose density and distribution.

Harper (1988) concluded that the Sukunka area provides good summer habitat for moose, but excessive snow depth forces migrations to winter range at lower elevations in the Sukunka and Pine river valleys. Balsam poplar riparian areas and shrub-grassland habitats were considered to be particularly important habitats during deep snow winters. Advancing seral stages of plant communities associated with fire suppression and intensive forest harvest were identified as another major factor limiting moose populations in the area. Harper (1988) estimated the realistic carrying capacity of MU 7-22 to be 1,800 animals.

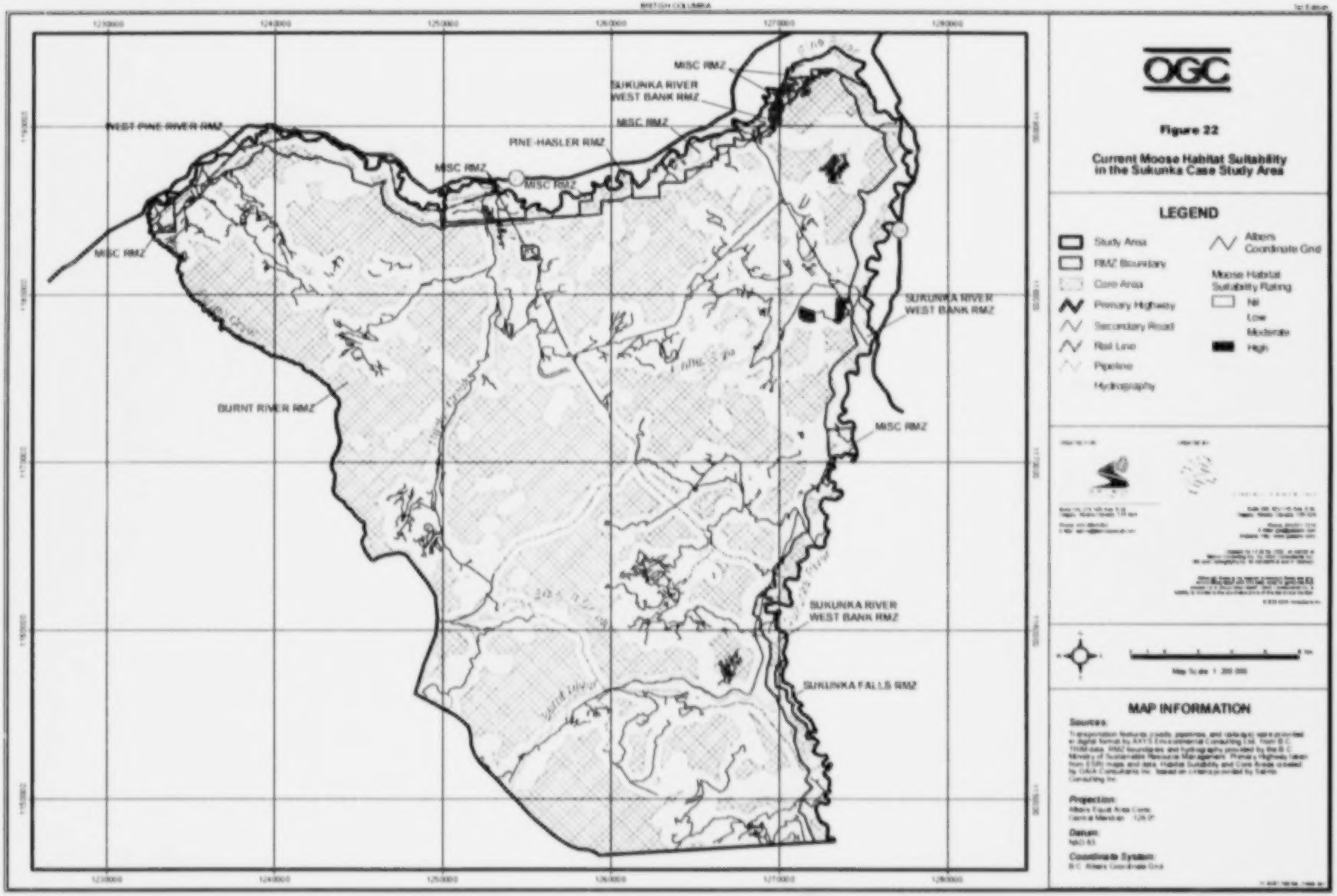


Figure 22

Current Moose Habitat Suitability in the Sukunka Case Study Area

MAP INFORMATION

Sources

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd. from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection

Albers Equal Area Conic

Central Meridian -126.0

Datum

NAD 83

Coordinate System

B.C. Albers Coordinate Grid

3.3.2.2 Population Trends

Harper (1988) estimated that 27,000 moose inhabited the Peace sub-region south of the Sikanni Chief River. Based on the knowledge of long-time regional wildlife staff, he also concluded that moose populations in the region had declined by roughly 50% between the early 1960's and early 1980's. Harper (1988) identified deteriorating habitat quality as the major contributing factor. He also concluded that the severe winter of 1981-1982, followed immediately by heavy tick infestations, had reduced some populations by 15%. Predation, agricultural conversion, and overharvest were also thought to have accelerated this decline in some areas.

Based on transect surveys in adjacent MU 7-21 (average density of 0.2/km^2), Harper (1988) estimated that the mid-1980's moose population in MU 7-22 was stable to decreasing at approximately 860 animals.

Sport hunter harvest data provide an index of population abundance, although harvest patterns are affected by regulatory changes and weather, among other factors. Moose harvest in MU 7-22 has varied from a low of 37 animals to a high of 107 animals, and no apparent trend is evident over the last 25 years (Figure 23).

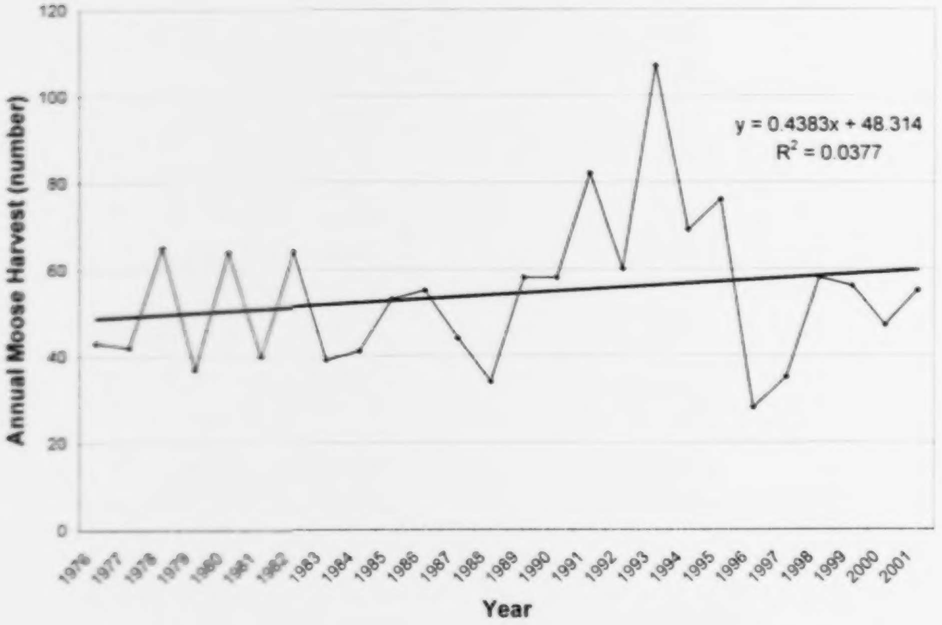


Figure 23. Annual moose harvest in Management Unit 7-45 (Sukunka Case Study area).

Annual harvest was dependent on hunter effort ($R^2 = 0.24$, $p < 0.05$), but harvest cycles can also be correlated with natural environmental factors. The population reduction in the early 1980's referenced by Harper (1988) is not evident in harvest data from the Sukunka area, although it was evident in the Sukunka Case Study area (Section 3.3.2.2 in Appendix 2). The increase displayed during the late 1980's corresponds to a 7 year period of mild winters beginning in 1984 that provided very good conditions for ungulate population growth (Figure 21). However, a dramatic increase in ATV use also occurred during this period that improved hunter success.

Moose harvest data from the Sukunka Case Study area suggest that the moose population has remained comparatively stable over the long-term although cyclical changes in relative abundance have occurred. Harvest data was found to provide a reasonable index of moose relative abundance in the Sukunka Case Study area and (Section 3.3.2.2 in Appendix 2). The cumulative effect of human disturbance (access creation and clearing) on moose abundance is discussed further below.

3.3.2.3 Cumulative Effects Evaluation

Harper (1988) estimated that annual human-caused mortality of moose in MU 7-22 was 90 animals, just over 10% of the population. Inferred sources of moose mortality were:

- 50: recreational hunter kill and estimated crippling loss,
- 25: suspected illegal kill (15% bulls, 60% cows, 25% calves),
- 5: estimated subsistence harvest, and
- 10: road and railway kill.

Because harvest was correlated with effort, moose hunter success (days per kill) statistics from MU 7-22 were used as a population index to relate changes in relative abundance to landscape habitat availability and land use. Hunter effort in this area has increased over the last 25 years, but the average number of days required for a hunter to kill a moose has been remained relatively stable although a slight increasing trend is evident (Figure 25).

A gradual decrease in hunter success could result from several factors: population decline, changes in harvest regulations, and changes in moose distribution or hunter access. As noted above, population decline does not appear to be an important factor. Stepwise linear regression was used to evaluate the influence of habitat, land use, and environmental factors on harvest success. The state of habitat and land use indicators was interpolated using trend equations developed from 1969, 1981, and current (late 1990's) data. No regression equations were statistically significant ($p<0.05$) and all R^2 values were poor, indicating that habitat and environmental factors were not good predictors of moose hunter success in the Sukunka Case Study area.

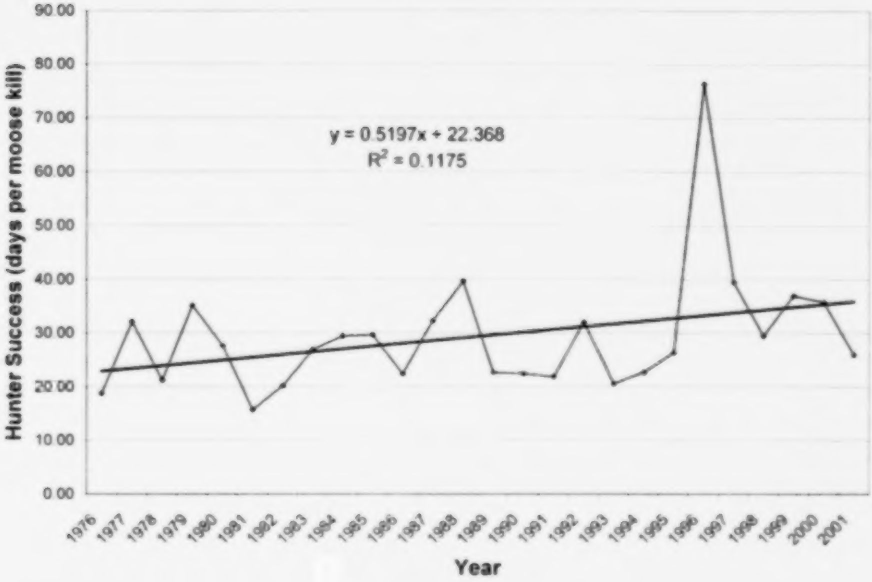


Figure 24. Historical moose harvest in MU 7-22.

Core areas with High and Moderate suitability moose habitat have declined in the Sukunka Case Study area over the last thirty years and currently comprise only 12% of available habitat (Table 6). This indicates that most moose in this area now inhabit 'edge' areas where disturbance and direct human mortality risk is increased and habitat effectiveness may be reduced.

This increased cumulative effects risk does not appear to have resulted in population declines for moose in the Sukunka Case Study area. This is likely due to a combination of factors including restrictive harvest regulations and greater availability of early seral stages (e.g., Franzmann 1978, McNicol and Gilbert 1980; Payne et al. 1988; reviewed in Culling and Culling 2001). Harvest-related reductions in abundance of legal animals are known to occur near disturbance features such as roads and cutblocks (e.g., Rempel et al. 1997), but these may not result in population changes at the regional scale (Schneider and Wasel 2000). Moose harvest regulations in the Sukunka Case Study area have become increasingly stringent since the late 1970's and legal harvest is currently limited to a small number of males that meet stringent antler size restrictions.

In summary, ongoing clearing and access development have reduced moose habitat effectiveness in the Sukunka area and reduced the availability of relatively undisturbed core areas. However, increased human mortality risk has not resulted in detectable population declines; this is likely due to application of restrictive harvest regulations that have offset increased access and moose vulnerability.

3.3.3 Woodland Caribou (*Rangifer tarandus*)

Woodland caribou have low ecological resilience; they are a habitat specialist, intolerant of human disturbance, and have low reproductive productivity (Bergerud 1974). Two woodland caribou ecotypes are present in northeast British Columbia, 'northern' and 'boreal' (Heard and Vagt 1998). Most individuals of the 'northern-ecotype' spend the spring, summer and fall in subalpine spruce/balsam and lodgepole pine forests and alpine tundra. During winter, they use a combination of windswept alpine and low- to high-elevation mature to old coniferous forests where lichens are most abundant and available. Deciduous and mixedwood forests appear to be avoided. Considerable individual and between-year variability in habitat use is observed. Some individuals remain in low elevation coniferous BWBS forests year-round (Edmonds and Bloomfield 1984; Sopuck 1985; Murray 1992; Backmeyer 1994; Brown and Hobson 1998; Apps et al. 2001, Culling and Culling 2001).

'Boreal-ecotype' caribou reside in low elevation coniferous forests year-round. Treed fens and bogs and black spruce forest appear to be preferred habitat. Distributions of the two caribou ecotypes may overlap during winter (Bradshaw et al. 1995; Stuart-Smith et al. 1997; Brown and Hobson 1998; Anderson et al. 1999, Rettie and Messier 2000).

Woodland caribou within the Sukunka Case Study area are assumed to represent the northern-ecotype. They occur at low densities and appear to be associated with high elevation subalpine and alpine habitat. Key factors limiting woodland caribou populations are:

- natural abiotic and biotic factors (wolf and bear predation, disease, snow, fire),
- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk), and
- habitat loss and alteration (clearing and alteration of seral stage distribution).

3.3.3.1 Habitat Availability and Suitability

Habitat in the Sukunka area was rated as High to Low capability (Class 2 to 4) for caribou by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use or seral stage. Current caribou habitat suitability ratings derived for the Sukunka Case Study area are summarized in Table 8 and depicted in Figure 25

Table 8. Current caribou habitat suitability in the Sukunka study area (area classified as core in parentheses).

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sukunka Overall	940 (821)	<1 (<1)	14,511 (6,169)	12 (5)	88,255 (39,369)	73 (32)	17,811 (5,051)	15 (4)
Burnt River RMZ	940 (821)	<1 (<1)	14,259 (6,112)	13 (6)	80,943 (37,580)	74 (34)	13,886 (4,207)	13 (4)
Misc RMZ	0 (0)	0 (0)	42 (0)	1 (0)	1,965 (248)	64 (8)	1,065 (77)	35 (3)
Pine-Hasler RMZ	0 (0)	0 (0)	0 (0)	0 (0)	469 (256)	79 (42)	126 (77)	(13)
Sukunka Falls and West Bank RMZs	0 (0)	0 (0)	78 (3)	1 (<1)	3,354 (966)	59 (17)	2,261 (704)	40 (12)
West Pine R. RMZ	0 (0)	0 (0)	132 (54)	6 (3)	1,524 (318)	72 (15)	474 (15)	22 (<1)

The Sukunka Case Study area has Low overall suitability for woodland caribou. Moderate and High Suitability habitat occurs in isolated patches of alpine tundra and subalpine forest on Highhat Mountain and Mount Jilg (Figure 25).

3.3.3.2 Population Trends

Harper (1988) crudely estimated the caribou population in the Peace sub-region to be about 1,100 and likely increasing, based on extensive reconnaissance aerial survey data. A major population crash is believed to have occurred in the sub-region in the early 1970's. This claim is supported by hunter harvest data. Populations are guessed to be about 25% of the 1960's populations. Possible causes – deep snow winters in the late 1960's and early 1970's, and possibly predation.

Limited anecdotal evidence indicates that woodland caribou populations are significantly lower than historical levels. Harper (1988) suggested that a major population crash had occurred in the sub-region in the early 1970's. Bergerud et al. (1984) note that the Pink Mountain-Prophet River caribou herd declined from at least 3,500 animals in 1969 to possibly only 300-400 animals in 1978. Harper (1988) suggested possible causes of the decline include deep snow winters in the late 1960's and early 1970's, and increased wolf predation.

Concurrent declines in woodland caribou populations were also observed in other populations in southern British Columbia and western Alberta between 1950 and 1980 (Edmonds and Bloomfield 1984; Stelfox and Stelfox 1993; Harding and McCullum 1994; Dzus 2001). In all areas, this decline occurred concurrently with an increase in road access and logging that is believed to have significantly increased mortality from hunters and wolves (Bergerud et al. 1984; Seip 1992; Harding and McCullum 1994). This is considered to be a good example of the cumulative effects of human development and habitat fragmentation (Harding and McCullum 1994).

A caribou herd of 60 individuals was believed to be present in the Burnt/Brazion area, (primarily to the west of the Sukunka study area) during the late 1980's. Approximately one third of these animals are assumed to winter in high elevation areas; the remainder appear to move to low elevation BWBS habitat east of the Case Study area (reviewed in Antoniuk 1994).

Excessive harvest is recognized as a possible threat to caribou populations and likely contributed to the major declines of the 1970's when liberal cow and bull seasons existed throughout the Peace sub-region. Bergerud et al. (1984) attributed the decline in the Pink Mountain-Prophet River herd to overharvest. This occurred because the Alaska Highway provided hunter access to caribou that came unusually far east, and because hunters used snow machines and cutlines to reach animals. Legal cow harvest was terminated in 1976 and bull seasons were significantly reduced in area and duration. A 5-point antler restriction was placed on bulls in 1986 to further reduce the legal harvest.

Annual direct caribou mortality in the Sukunka area is currently assumed to be low, although the extent of subsistence and illegal harvest are unknown. On average, one mature bull has been harvested in MU 7-22 since 1976. Vehicle mortality of woodland caribou is considered to very low in the Sukunka Case Study area (Antoniuk 1994).

3.3.3.3 Cumulative Effects Evaluation

Established cumulative effects indicators and thresholds for caribou were reviewed in Section 6.1.3 of Appendix 1.

Relatively undisturbed core areas with High and Moderate suitability woodland caribou habitat have declined in the Sukunka Case Study area over the last thirty years and currently comprise 5% of available habitat (Table 9); generalized core areas currently represent 40% of the study area (Figure 26). This is below the 50% to 60% caribou persistence threshold (Section 6.1.3 in Appendix 1), and High and Moderate suitability core area is well below this threshold. Total access corridor density in this area is lower than the 3 km/km^2 woodland caribou persistence threshold (Section 6.1.3 in Appendix 1).

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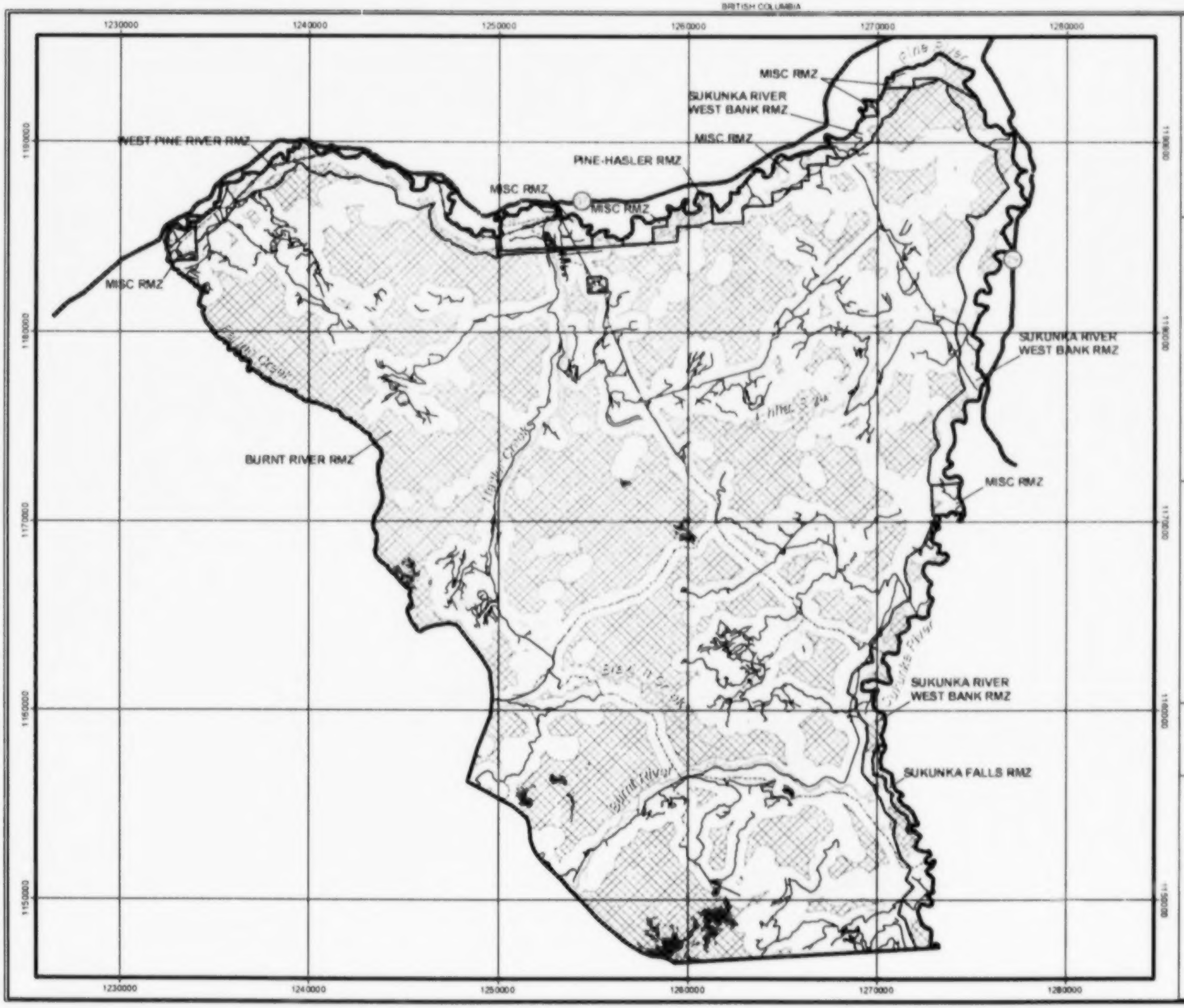
Figure 25

Current Caribou Habitat Suitability in the Sukunka Case Study Area



LEGEND

- Study Area
- RMZ Boundary
- Core Area
- Primary Highway
- Secondary Road
- Rail Line
- Pipeline
- Hydrography
- Albers Coordinate Grid

Caribou Habitat Suitability Rating

- ☐ Nil
- Low
- Moderate
- ■ High

Map Scale 1 : 250 000

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

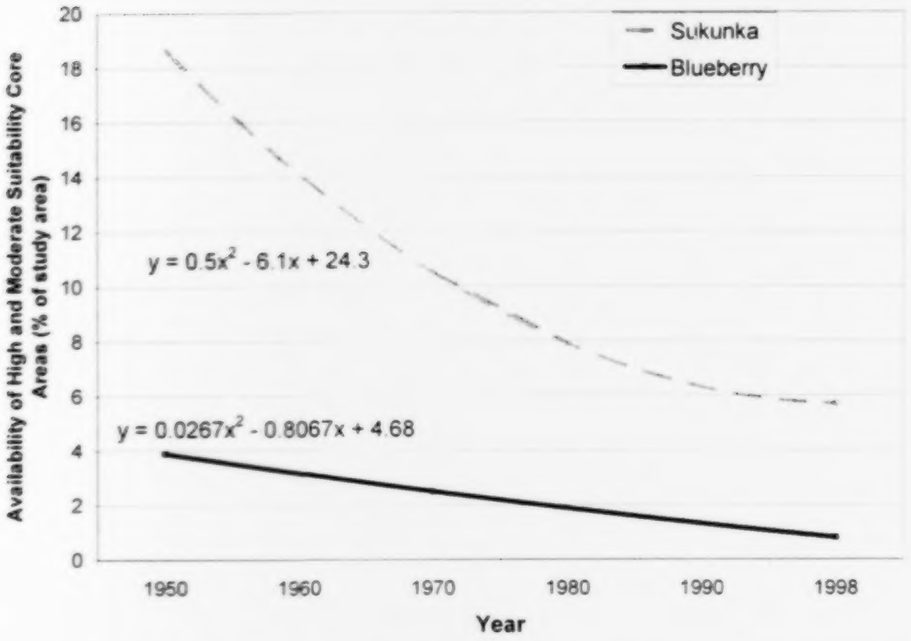


Figure 26. Trends in availability of High and Moderate Suitability caribou core habitat.

Available information suggests that the probability of woodland caribou persistence in the Sukunka Case Study area is reduced by combined human disturbance.

3.3.4 Elk (*Cervus elaphus*)

Elk are highly sought after by recreational hunters and are increasing in abundance in northeast British Columbia. Elk are a habitat generalist with moderate reproductive potential. They are generally intolerant of human disturbance, but habituate to predictable, non-threatening activities. Key factors limiting elk populations are:

- natural abiotic and biotic factors (predation, snow depth, disease, fire),
- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk), and
- habitat loss and alteration (clearing, fire suppression, reduced habitat effectiveness near human activity).

3.3.4.1 Habitat Availability and Suitability

Habitat in the Sukunka Case Study area was rated as Moderate to High capability (Class 2 to 3) for elk by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Current elk habitat suitability ratings derived for the Blueberry Case Study are summarized in Table 9 and depicted in Figure 27.

Table 9. Current elk habitat suitability in the Sukunka study area (area classified as core in parentheses).

Analysis Unit	**Suitability Class**							
	High		**Moderate**		**Low**		**Nil**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Sukunka Overall	80 (0)	<1 (0)	26,265 (9,673)	22 (8)	91,376 (41,141)	75 (34)	3,795 (596)	3 (<1)
Burnt River RMZ	63 (0)	<1 (0)	19,598 (8,187)	18 (7)	87,110 (40,064)	79 (36)	3,258 (469)	3 (<1)
Misc RMZ	0 (0)	0 (0)	1,295 (86)	42 (3)	1,680 (206)	55 (7)	97 (4)	3 (<1)
Pine-Hasler RMZ	0 (0)	0 (0)	225 (115)	38 (19)	350 (216)	59 (36)	20 (3)	3 (0)
Sukunka Falls and West Bank RMZs	0 (0)	0 (0)	4,004 (1,020)	70 (18)	1,318 (535)	23 (9)	370 (119)	7 (2)
West Pine R. RMZ	17 (0)	<1 (0)	1,143 (265)	54 (12)	919 (122)	43 (6)	51 (1)	2 (<1)

Approximately 22% of the Sukunka Case Study area is currently rated as Moderate to High Suitability elk habitat; most is located at lower elevations in river and creek valleys. Habitat suitability of burned, logged, or cleared areas between 5 and 20 years old is increased for 'edge' species such as elk, moose, and deer (Westworth and Telfer 1993; Puttock et al. 1996).

1st Edition

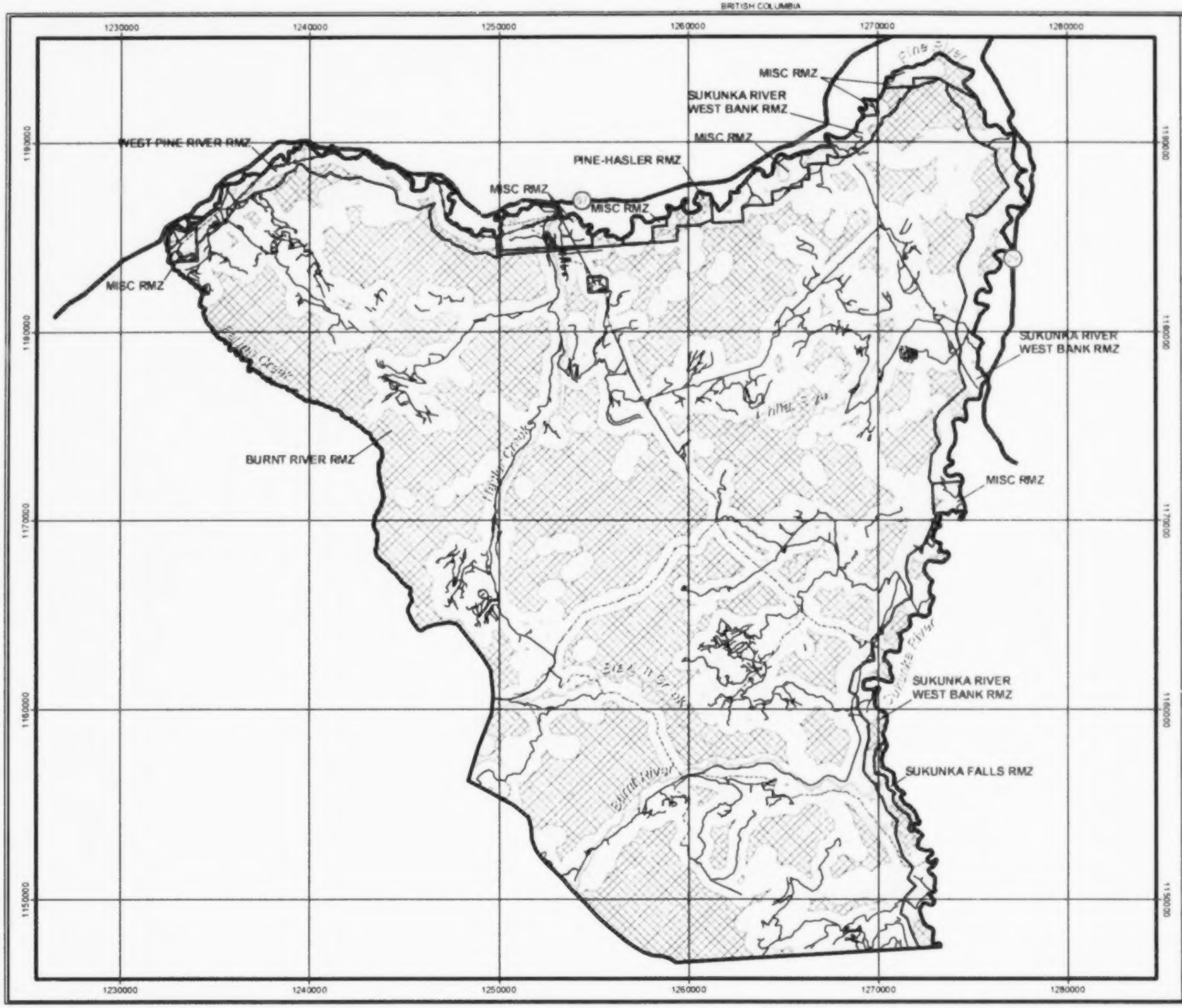


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Figure 27

Current Elk Habitat Suitability in the Sukunka Case Study Area

LEGEND

▭	Study Area
▭	RMZ Boundary
▨	Core Area
∧	Primary Highway
∧	Secondary Road
∧	Rail Line
∧	Pipeline
	Hydrography
∧	Albers Coordinate Grid

Elk Habitat Suitability Rating

☐	Nil
	Low
	Moderate
■	High

Map Scale 1:200 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

Elk in the Sukunka Case Study area appear to summer in subalpine and alpine habitat and move to suitable overwintering habitat comprised of steep southwest aspect shrub/grass communities. Harper (1988) concluded that elk density in MU 7-22 was well below capability based on biophysical mapping conducted for the area.

3.3.4.2 Population Trends

Elk are believed to have been historically common along the Peace River and its tributaries but disappeared along with wood bison in the mid-1800's. Elk populations in much of the northeast region have undergone dramatic expansion in the past two decades. The source for much of this expansion was a small herd on the lower Moberly River, which was first noted during an aerial survey in 1966. By 1988 the population in the Peace sub-region was estimated at 890 and reported to be increasing rapidly (16% per year; Harper 1988). Elk herds now occur throughout the sub-region where sufficient critical wintering habitat exists.

Harper (1988) estimated that 50 elk were present in MU 7-22 in the mid-1980's and numbers were considered to be increasing as a result of prescribed burns, transplants into the Sukunka drainage, and logging that increased the abundance of early seral stages (reviewed in Antoniuk 1994). Harper (1988) identified a management objective of 300 elk in MU 7-22 by the year 2000.

Sport hunter harvest data provide an index of population abundance, although harvest patterns are affected by regulatory changes and weather, among other factors. Prior to 1985, elk hunting in the Peace sub-region south of the Sikanni Chief River was confined to two MUs in the Murray and Wapiti river drainages. Elk hunting in the Sukunka area was allowed beginning in 1986, and by 1990, general bull seasons were established in virtually all MUs where elk were known to exist.

Annual elk harvest levels in MU 7-22 was low prior to 1989, but has since averaged 10 animals per year. Annual harvest was dependent on hunter effort ($R^2 = 0.38$, $p<0.05$), but harvest is also affected by natural environmental factors. The increase displayed during the late 1980's corresponds to a 7 year period of mild winters beginning in 1984 that provided very good conditions for ungulate population growth (Figure 21).

3.3.4.3 Cumulative Effects Evaluation

In the Peace Sub-region, the hunting seasons are designed to allow the elk populations to continue to increase where appropriate habitat is available. Limited entry cow seasons have been established to control elk populations. No specific objectives have been established for elk population numbers (e.g., bull:cow ratios, calf recruitment or other population characteristics. Results of a province-wide review suggest that population growth is currently limited by the survival and recruitment of calves. Numbers of the major predators have likely increased substantially over the past decade, resulting in increased predation on elk (Raedeke Associates Inc. 1998).

Results from the sensitivity analysis reveal the importance of several population parameters, namely calf recruitment rates, cow elk survival rates, and random (stochastic) variables that affect survival. Simulations suggest that recruitment rates of 26.4 calves:100 cows would be required in order to stabilize growth; calf recruitment rate in the East Kootenays is very low and below the level considered adequate to maintain the population in the long-term (Raedeke Associates Inc. 1998).

Models relating elk habitat effectiveness to road and trail density have been developed for hunted elk populations in Oregon (e.g., Thomas et al. 1979, 1988; Lyon 1983, 1984). These models suggest that current road and trail density in the Sukunka Case Study area has reduced elk habitat effectiveness by 15% to 50%. This is consistent with calculations that less than 10% of the Sukunka Case Study area provides Moderate and High suitability habitat within relatively undisturbed core areas.

However, recent work to validate a commonly used elk-road model confirmed that elk avoided roads during spring and summer, but found that the model overestimates the relative loss of habitat effectiveness (Rowland et al. 2000). Calculated reductions in habitat effectiveness have not affected populations in the Sukunka area, as the expansion of the road and trail network has coincided with a dramatic increase in elk numbers. O'Neill (1993) also concluded that loss in habitat effectiveness is not a significant issue for many species in this region.

Insufficient data were available to directly examine the effect of combined human activities on elk abundance in the Sukunka Case Study area. Ongoing clearing and access development have reduced elk habitat effectiveness, but the lack of suitable wintering habitat appears to be primary factor limiting elk in this area.

3.3.5 Grizzly Bear (*Ursus arctos*)

The grizzly bear is widely used as an umbrella species for the assessment and management of cumulative effects at regional scales (e.g., Noss et al. 1996; Kansas 2002). Grizzly bear are Blue-listed in British Columbia, classed as Special Concern by COSEWIC (2002), and are classified as an Identified Wildlife Species (BCF and MELP 1999a). Estimated grizzly bear numbers are below historic and current potential in northeast British Columbia and have been extirpated from the Peace River lowlands. Local populations elsewhere in the region are not considered to be at risk (Cannings et al. 1999; Culling and Culling 2001).

Grizzly bears are considered to have low ecological resilience (Weaver et al. 1996). Reproductive rate is the lowest recorded among North American land mammals. Subadult female dispersal outside maternal home ranges is rare in much of British Columbia, so areas where all resident adult females have been killed are usually not recolonized (reviewed in MELP 1995, 1997; Cannings et al. 1999; Culling and Culling 2001).

Key factors limiting grizzly bear populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, wildlife management actions),
- habitat loss and alteration (clearing, fire suppression, reduced habitat effectiveness near human activity), and
- natural biotic and abiotic factors (severe weather, cannibalism by males).

3.3.5.1 Habitat Availability and Suitability

Habitat in the Sukunka area was rated as High to Moderate capability (Class 2 to 3) for grizzly bear by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Current grizzly bear habitat suitability derived for the Blueberry Case Study is summarized in Table 10 and depicted in Figure 28.

Table 10. Current grizzly bear habitat suitability in the Sukunka study area (area classified as core in parentheses).

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Sukunka Overall	434 (329)	<1 (<1)	64,918 (28,029)	53 (23)	52,370 (22,456)	43 (18)	3,795 (596)	3 (<1)
Burnt River RMZ	84 (50)	<1 (<1)	58,084 (26,418)	53 (24)	48,603 (21,783)	44 (20)	3,258 (469)	3 (<1)
Misc RMZ	191 (149)	6 (5)	1,310 (82)	43 (3)	1,473 (62)	48 (2)	97 (4)	3 (<1)
Pine-Hasler RMZ	53 (34)	9 (6)	294 (146)	49 (25)	229 (150)	38 (25)	20 (3)	3 (<1)
Sukunka Falls/West Bank RMZs	103 (97)	2 (2)	3,805 (1,066)	67 (19)	1,414 (393)	25 (7)	370 (119)	7 (2)
West Pine R. RMZ	3 (0)	<1 (0)	1,426 (318)	67 (15)	651 (68)	31 (3)	51 (1)	2 (<1)

Just over half of the Sukunka Case Study area is rated as Moderate or High suitability for grizzly bear and this habitat is widely distributed throughout the area (Figure 28) in mature subalpine forest and lower elevation riparian areas (Figure 3).

3.3.5.2 Population Trends

No current and historical data on grizzly bear populations within MU 7-2, including the Sukunka Case Study Area, were located. Harper (1988) indirectly estimated the grizzly bear population to be 1,172 in the Peace sub-region from compulsory inspection hunter harvest data. He also estimated that 144 grizzly bear occurred in MU 7-22, an average density of 1 bear/30 km^2. Excessive legal and illegal harvest exacerbated by access development was identified by (Harper 1988) as the only major impact on grizzly bear populations in the Peace sub-region. There is no evidence to indicate the direction of short- or long-term population trends within the Case Study area.

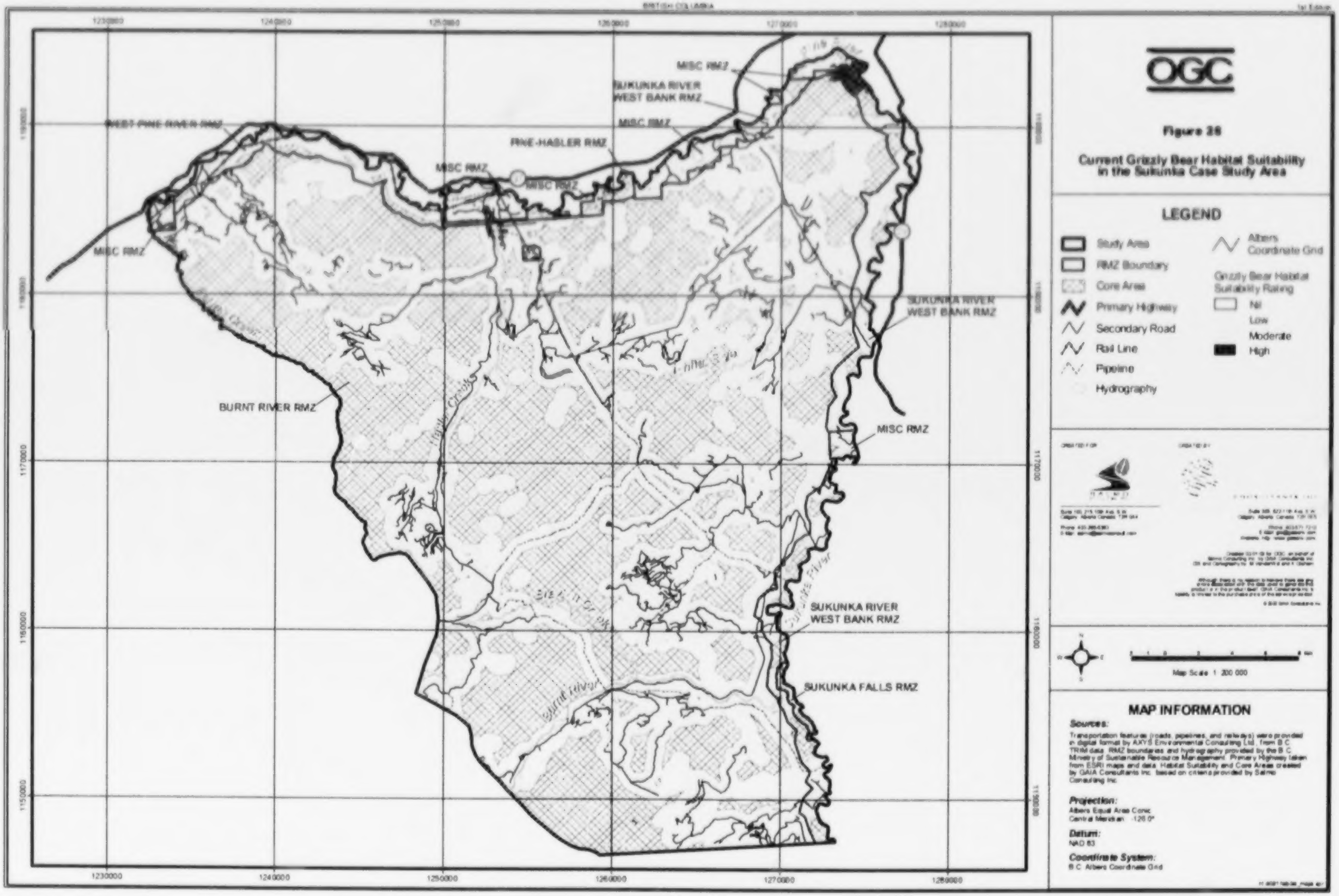
3.3.5.3 Cumulative Effects Evaluation

Development of cumulative effects assessment methods for grizzly bear began in the early 1980's and are now well established and generally accepted (Gibeau et al. 1996; Kansas 2002). These include three components: habitat effectiveness (integrating habitat availability, quality, and disturbance); mortality; and connectivity (linkage zone prediction). These methods, and established cumulative effects indicators and thresholds for grizzly bear were reviewed in Section 6.1.2 of Appendix 1.

Direct and indirect human-cause mortality appears to be the most significant factor affecting grizzly bear populations in western North America (Mattson 1993: ESGBP 1998; McLellan et al. 1999). Most grizzly bear mortality occurs within 500 m of roads and facilities and 200 m of backcountry facilities and trails (Mattson 1993; Gibeau et al. 1996; Mace et al. 1996; ESGBP 1998). Female survival is believed to be important for grizzly bear population persistence. Development activities that increase mortality of adult females may result in a reduction in grizzly bear populations (reviewed in Culling and Culling 2001). Because of their low productivity, grizzly bear populations respond slowly to impacts that produce a change in status.

In British Columbia, maximum sustainable harvest has been set at 4% of the estimated population, including kills from all sources. The unreported kill from natural mortality and accidental and illegal kills is standardized at 50% of the total kill unless documentation indicates otherwise. Total harvest should include no greater than 33% females, and hunting seasons are not permitted in management units with fewer than 26 bears (MELP 1995).

Annual grizzly bear sport harvest data from MU 7-22 (Figure 29) show that prior to 1998, total harvest, and female harvest frequently exceeded the respective sustainable thresholds of 4% of the estimated MU population (5.8 bears) and 33% of total kill (2 females) about half the time, excluding unreported kills.



OGC

Figure 28

Current Grizzly Bear Habitat Suitability in the Sukunka Case Study Area

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

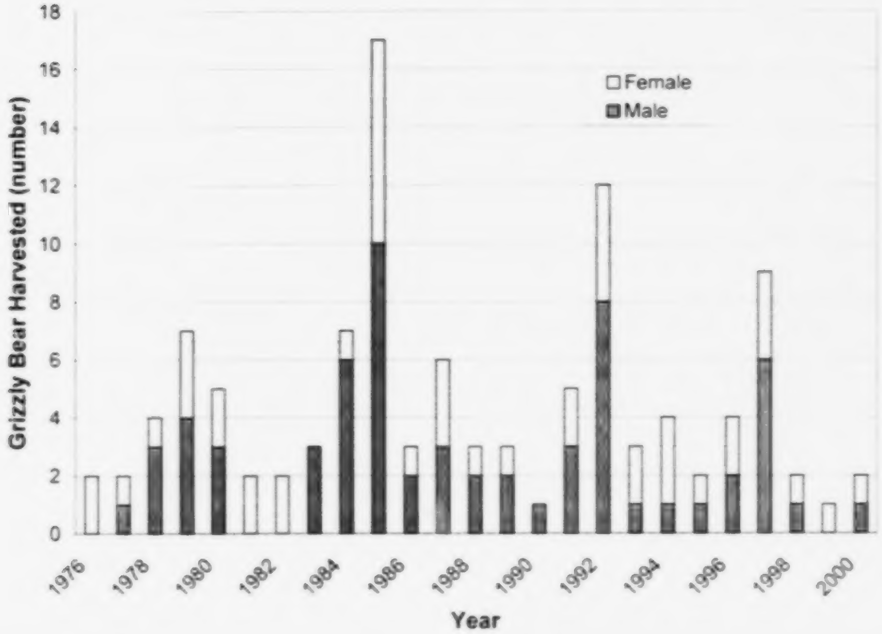


Figure 29. Annual grizzly bear harvest in Management Unit 7-22 (Sukunka Case Study area).

Open road density thresholds of 0.45 to 0.6 km/km^2 have been established or proposed for bears in the Greater Yellowstone Grizzly Bear Recovery Zone (Servheen 1993). A threshold of 0.6 km/km^2 has also been identified to protect high quality grizzly bear habitat in British Columbia (BCF and MELP 1999a). Current average road and trail density exceeds the established 0.6 km/km^2 threshold in the overall Sukunka Case Study area and most RMZs (Figure 8, Appendix A). The Brazion Creek and Burnt River subwatersheds contain the largest intact core areas (Figure 28).

Minimum core area thresholds of >60% of available habitat have also been identified to ensure grizzly bear persistence in British Columbia (NCGBRT 2001) and elsewhere (Gibeau 2000). Remaining core area is below this threshold in the overall Sukunka Case Study area and all RMZs (Appendix A).

Insufficient data were available to directly examine the cumulative effect of development on grizzly bear abundance in the Sukunka Case Study area. However, mortality, habitat effectiveness, and core area analyses all indicate that the probability that a viable grizzly bear population will persist in the Sukunka Case Study area is reduced without lower mortality or continued immigration from less disturbed areas.

3.3.6 Other Wildlife

3.3.6.1 Deer

The majority of the Peace sub-region mule deer and white-tailed deer are concentrated in the Peace Lowlands ecosection east of the Sukunka area, that has the mildest climate and lowest snow depths. Critical wintering habitat for mule deer is largely associated with southwest aspect shrub/grassland habitat along major river valleys such as the Peace, Pine, and Moberly (core wintering habitat). White-tailed deer densities are highest in areas of moderate agricultural development. Deer are near the northern limit of their distribution in this area and abundance can fluctuate widely in response to winter severity. Deer are considered to have high ecological resilience because they have high reproductive potential and can recover quickly from population declines.

Habitat in the Sukunka area was rated as Moderate to Low capability (Class 3 to 4) for mule and white-tailed deer by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Highest capability habitat occurs in the Sukunka and Pine river valleys.

The limited extent of suitable winter habitat restricts the distribution of deer within the Sukunka Case Study area. Radio-telemetry data have illustrated that the region's mule deer population is comprised of both migratory and resident subpopulations. During summer, migratory deer move from the core wintering habitat to outlying habitats, including those found in the Sukunka Case Study area. Resident mule deer winter in small areas of suitable habitat along the Pine and Sukunka river escarpments. Harper (1988) estimated the mule deer population to be 11,500 in the Peace sub-region, and 150 within MU 7-22.

White-tailed deer are most abundant in agricultural areas northeast of Sukunka Case Study area, and are occasionally sighted elsewhere in the region. Harper (1988) estimated the sub-regional white-tailed deer population at 2,000 to 4,000, with no estimate for MU 7-22.

Deer harvest statistics for MU 7-22 are summarized in Figure 30. Total white-tailed deer harvest increased in the late 1980's following several mild winters (Figure 21) and has averaged 30 animals between 1990 and 2000. Mule deer harvest also increased in the late 1980's, but harvest levels have been affected by provincial government regulations adopted to reduce the harvest of mature mule deer bucks.

Clearing and agricultural conversion in the Pine and Sukunka river valleys has probably improved habitat suitability for deer, although winter severity appears to be the primary factor limiting deer populations in the Sukunka Case Study area. Increased access and human development has increased mortality risk for both species, and harvest has affected population parameters of mule deer. Continued application of restrictive harvest regulations will likely be necessary to offset increased mule deer vulnerability.

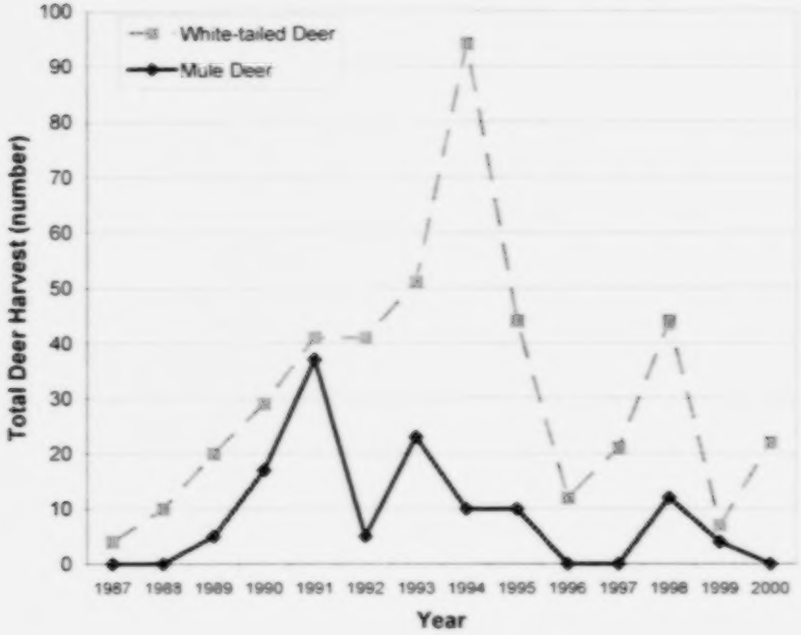


Figure 30. Total yearly harvest of mule deer and white-tailed deer in MU 7-22 (Sukunka Case Study area).

3.3.6.2 Gray Wolf (*Canis lupus*)

While the current distribution of the gray wolf in North America is much reduced from historic range and wolves are classified as endangered in the contiguous United States (Paquet and Hackman 1995), they are not considered either threatened or vulnerable in British Columbia. Wolf densities in northeast British Columbia are moderate to high (Culling and Culling 2001). Wolves are considered to have moderate ecological resilience because of their high reproductive potential and dispersal capabilities and ability to use a variety of prey species (Weaver et al. 1996).

Habitat in the Sukunka area was rated as Very High to Low capability (Class 1 to 4) for wolf by the Northeastern British Columbia Wildlife Biophysical Project (MELP 1994). This rating, based on 1:250,000 scale biogeoclimatic mapping, considered capability to support wildlife, irrespective of current land use. Very High capability habitat was limited to the Sukunka and Pine river valleys.

Harper (1988) crudely estimated a wolf population of 520 in the Peace sub-region, and 22 to 32 animals in 4 packs in MU 7-22. This was calculated by extrapolating density estimates from other studies or by assuming pack size averaged 8 wolves per pack and 1 pack per major watershed. A substantial increase in wolf numbers was believed to have occurred in 1983 and 1984. Direct and indirect human mortality is the primary factor limiting wolf populations (reviewed in Weaver et al. 1996).

Combined human development and activity may have one of two effects on wolf distribution and abundance. Most researchers have found that wolves tend to avoid human settlements and areas with high levels of human activity (Thiel 1985; Jensen et al. 1986; Mech 1989; Thurber et al. 1994; Mladenoff et al. 1995; Whittington 2002). In these areas, wolves appear to select areas with road and trail densities less than 0.6 km/km^2.

This relationship does not appear to hold for less populated areas in the Canadian Rocky Mountains and boreal forest (reviewed in Jalkotzy et al. 1998 and Whittington 2002). Observations from northeast British Columbia and northwest Alberta also suggest that wolves may habituate to human activity if they are not harassed or persecuted (EES 1998, 1999 in Culling and Culling 2001). In these areas, wolf densities may increase as a result of human activity, and as described below, impacts on prey species are the cumulative effect of most concern.

Wolves are the chief predator of large mammals in northeast British Columbia (Harper 1988; Bergerud and Elliot 1998). Wolf densities in boreal systems appear to be sustained primarily by moose, with incidental predation on secondary prey species such as elk, caribou, and deer. Large scale or localized habitat alterations that result from combined development activities can increase the abundance of edge species such as moose, elk, and deer and support increased wolf densities (reviewed in Culling and Culling 2001). Increased wolf density has been shown to decrease density of both primary and secondary prey (Bergerud and Elliot 1998). Although no clear relationship has been demonstrated, the presence of roads, trails and cutlines may increase predation by providing packed travel surfaces or longer sight lines that increase wolf searching efficiency and range (Bergerud et al. 1984; Thurber et al. 1994; James 1999; James and Stuart-Smith 2000). This may be especially significant for woodland caribou because of their low ecological resilience (see Section 6.1.3 in Appendix 1).

Reported yearly trapper wolf harvest in MU 7-22 has averaged 2 wolves per year, with wolves taken only every several years.

Insufficient data are available to directly examine the cumulative effect of development on wolf abundance in the Sukunka Case Study area. Available data do suggest that wolf have persisted in this area where road densities are above thresholds documented for more populated areas. This confirms observations from elsewhere in the Canadian Rocky Mountains and boreal forest.

3.3.7 Fish

The Sukunka Case Study Area lies entirely within the Pine River drainage, a sub-basin of the Peace River watershed. The northern boundary of the study area is defined by the Pine River mainstem and the east boundary by the Sukunka River mainstem, a large tributary to the Pine River. Most of the case study area is drained by tributaries to the

Sukunka River, including the Burnt River, and Rocky, Brazion, and Highhat creeks. The northern edge of the study area is drained by a series of Pine River tributaries, including Caron, Goodrich, Hasler, and Falling creeks.

Streams within the Sukunka Case Study Area are generally moderate-gradient, low-turbidity systems originating in the Rocky Mountain Foothills. In contrast to the Blueberry Case Study Area, stream banks and valley slopes typically exhibit a relatively high degree of stability and low erodibility, resulting in low suspended solids levels and high water clarity. Streambed substrates are generally composed of cobble and gravel, with a low proportion of fines. Habitat typically consists of riffle-pool configurations with fish rearing cover provided by deep pools, large woody debris, and boulders.

Existing fisheries information suggests that the Sukunka Case Study Area supports a moderate number of sport-fish species and a relatively low number of forage fish species. Non-sport species include lake chub (*Couesius plumbeus*), slimy sculpin (*Cottus cognatus*), longnose sucker (*Catostomus catostomus*), and longnose dace (*Rhinichthys cataractae*).

Past sampling within the case study area has identified five sport-fish species, including Arctic grayling, bull trout, northern pike (*Esox lucius*), mountain whitefish and rainbow trout. Bull trout, Arctic grayling, mountain whitefish and rainbow trout are widely distributed throughout the study area occupying both mainstem and tributary habitats on a seasonal basis. The distribution of northern pike and non-sport species is much more restricted and largely limited to the Pine and Sukunka rivers.

Waterfalls form impassable barriers on many streams, including the Sukunka River, Burnt River, Brazion Creek, Highhat Creek, and Falling Creek. Although barriers preclude upstream fish presence on smaller systems, upstream-resident fish populations occur above the lower Sukunka Falls and the lower Brazion Creek Falls.

Specific fisheries concerns within the study area include a genetically-isolated, resident bull trout population in upper Brazion Creek, a migratory sub-population of Sukunka River bull trout which spawns in the upper Burnt and lower North Burnt Rivers, and the lower Sukunka River Arctic grayling population, particularly that portion of the adult component which over-summers in the lower Burnt River.

In contrast to the Blueberry Case Study Area, recreational angling opportunities within the Sukunka Case Study Area are significant and attractive. Bull trout stage in the lower Burnt River during late summer prior to spawning; concentrations of Arctic grayling are also found in this area during late summer because it provides critical feeding habitat. The potential for overharvest was increased when an all-weather road was constructed into this area in 1990, greatly improving public access.

Insufficient data were available to examine the effect of watershed development on bull trout, rainbow trout, northern pike, and mountain whitefish. Potential cumulative effects on Arctic grayling are discussed below.

3.3.7.1 Arctic Grayling (*Thymallus arcticus*)

Arctic grayling is a coldwater species that is very sensitive to fishing pressure and habitat alteration. Grayling distribution appears to be limited by mid-summer temperature regime, and appears to follow elevation and temperature isotherms (O'Neil and Patalas 2001). In British Columbia, some populations are in severe decline and have been identified as a species 'requiring special forestry considerations' (Haas 1998). Some Arctic grayling populations migrate large distances between spawning, feeding, and overwintering areas; small streams with clean substrate are required for spawning (reviewed in Ford et al. 1995). This species is considered to have low ecological resilience due to ease of capture, low annual production, high natural mortality, short lifespan, limited critical habitat availability, susceptibility to movement barriers, and significant year-to-year climatic influence (reviewed in Ursus and Salmo 2002).

In the Sukunka Case Study area, natural environmental changes (e.g., drought, beaver dams, spring water temperatures) will affect grayling reproductive success, recruitment, and survival. Sources of cumulative effects on this species include harvest, siltation effects on spawning and juvenile rearing habitat, and the exclusion of juvenile grayling from seasonal rearing habitat through the creation of barriers at road and pipeline crossings. Watershed indicators indicate that current cumulative effects hazard level is Medium in watercourses of the Sukunka Case Study area (Section 3.2.4). Insufficient data were available to examine the effect of watershed development on Arctic grayling distribution or abundance. An ongoing study on an Arctic grayling population using the lower Burnt River provides evidence of cumulative effects associated with legal and illegal angling; a summary of this study is provided below.

Prior to 1990 access into the lower Burnt River watershed (Figure 8) was limited to an abandoned logging road that paralleled the Burnt River along most of its fishable length. A daily harvest of 5 Arctic grayling of any size was permitted, however angler effort was restricted due to poor access. In 1990, following the discovery of significant gas reserves within the watershed, permanent all-weather access was established.

At this point, BC Environment's knowledge of the fish populations was limited to anecdotal information. Preliminary sampling in the summer of 1991 indicated that a significant over-summering population of Arctic grayling was at risk due to liberal harvest quotas combined with the new access. In the fall of 1991, BC Environment reduced grayling and bull trout catch quotas to 0 and implemented single barbless hook and bait ban regulations for the Burnt River drainage. In 2000, these regulations were further modified, restricting angling in the Burnt River to artificial fly fishing only.

Beginning in 1992 and continuing to the present, fish populations in the Burnt River have been monitored by BC Environment. Snorkel counts conducted within representative sections in August-September of 1992, 1993, and 1998 through 2002, provide a time series of abundance estimates for Arctic grayling during peak summer distribution in the Burnt River. Figure 31 shows the mean number of grayling per kilometre of stream from a 2 km stretch in the most heavily fished section of the River. This reach includes the river from the lowermost falls downstream to a large, easily accessible pool (the 'Lower

Pool'). Data for sampling years 1992, 1993 and 1998, 1999, 2001, and 2002 are included; data from the 2000 sampling year are not considered to be directly comparable due to the late timing of snorkel counts and flood conditions which reduced.

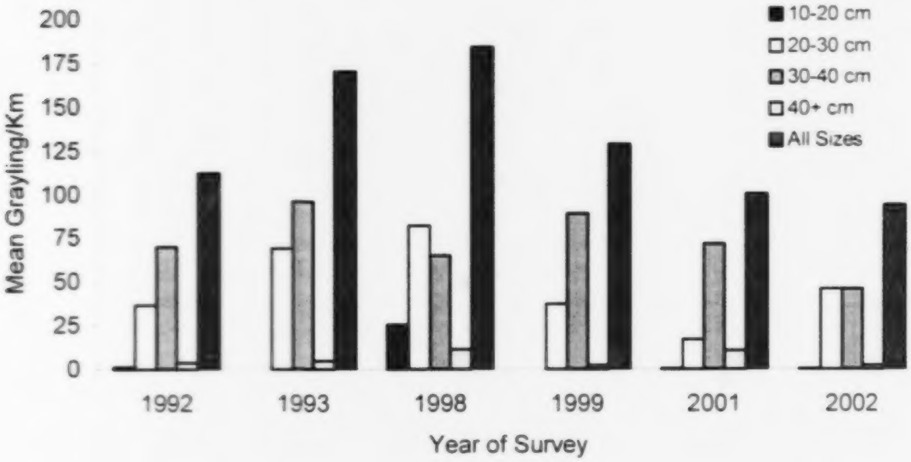


Figure 31. Estimated density of Arctic grayling per kilometre in lower Burnt River, 1992 to 2002.

Overall Arctic grayling relative abundance increased until 1998, and has subsequently declined to a level approximately 10% to 20% below that documented in 1992. Although natural variability is evident, the abundance of the 20-30 cm juvenile size class appears to have declined. This decline may represent lower recruitment resulting from habitat alteration and loss elsewhere within the Sukunka watershed.

Despite a significant enforcement effort on the part of local conservation officers and posted signs describing regulations pertaining to the Burnt River, angler non-compliance and incidental mortality resulting from hooking and handling stress are considered to be significant factors influencing the observed decline. Remains of grayling used for bull trout bait are commonly found at popular angling sites along the river. Similarly, injured and damaged grayling have frequently been seen during snorkel counts since implementation of the catch and release regulation. Angling gear fitted with baited treble hooks is often observed snagged on the river bottom and anglers using large treble hooks and bait are frequently encountered during snorkel surveys (T. Euchner, pers. obs.).

4. CUMULATIVE EFFECTS INDICATORS AND THRESHOLDS

Cumulative effects management is largely focused on defining how and where human activities can be continued without irreversible net harm to habitat, fish and wildlife populations, or biodiversity. Most cumulative effects ultimately result from the combined effects of small routine projects or activities. Nevertheless, the potential cumulative effects of these everyday activities are rarely considered in a formal way. This is at least partly due to the perception that complex, expensive, and time-consuming technical methods such as species-specific habitat modelling are required. Available literature and practice in other jurisdictions demonstrates that cumulative effects indicators can be used to quickly and economically assess the probability of adverse cumulative effects.

A suite of complementary land use and habitat indicators was identified as the most appropriate for assessing and managing cumulative effects on fish and wildlife habitat and populations in northeast British Columbia (Appendix 1). These indicators quantify the area affected directly and indirectly by access corridors and the number and size of relatively undisturbed areas. They are:

Land Use Indicators

1. Access density (km of linear corridors per unit area).
2. Stream crossing index (number of crossings per km of stream).
3. Activity setbacks.

Habitat Indicators

1. Core area (% of analysis area).
2. Patch and corridor size (area in ha or width in m).
3. No Net Habitat Loss.

4.1 APPLICABILITY OF LAND USE AND HABITAT INDICATORS

This section evaluates the suitability of recommended land use and habitat indicators for cumulative effects assessment and management in northeast British Columbia based on data from the Sukunka Case Study area.

4.1.1 Access Density

Access density is considered to be a useful land use indicator because it integrates the many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance (Forman and Hersperger 1996). Results from the Blueberry Case Study (Appendix 2) confirm that access density can be used to document cumulative effects in northeast British Columbia.

Road density, trail density, and total corridor density provided statistically significant ($p<0.05$) predictions of a moose population index (harvest success), in the Blueberry Case Study area (Appendix 2). This finding is consistent with studies from elsewhere that demonstrate increased mortality risk near roads and trails (Appendix 1).

Average road and trail density was also found to be a good predictor of remaining core area in both Case Studies. The core area-road and trail density relationship graph provided in Figure 32 for the Sukunka Case Study area demonstrates that availability of relatively undisturbed core areas decreases exponentially as road and trail density increases. In the Blueberry and Sukunka areas, 60%, 40%, 30%, and 10% core area thresholds summarized in Appendix 1 correspond to average road and trail densities of 0.4 km/km^2, 0.72 km/km^2, 1 km/km^2, and 1.79 km/km^2, respectively.

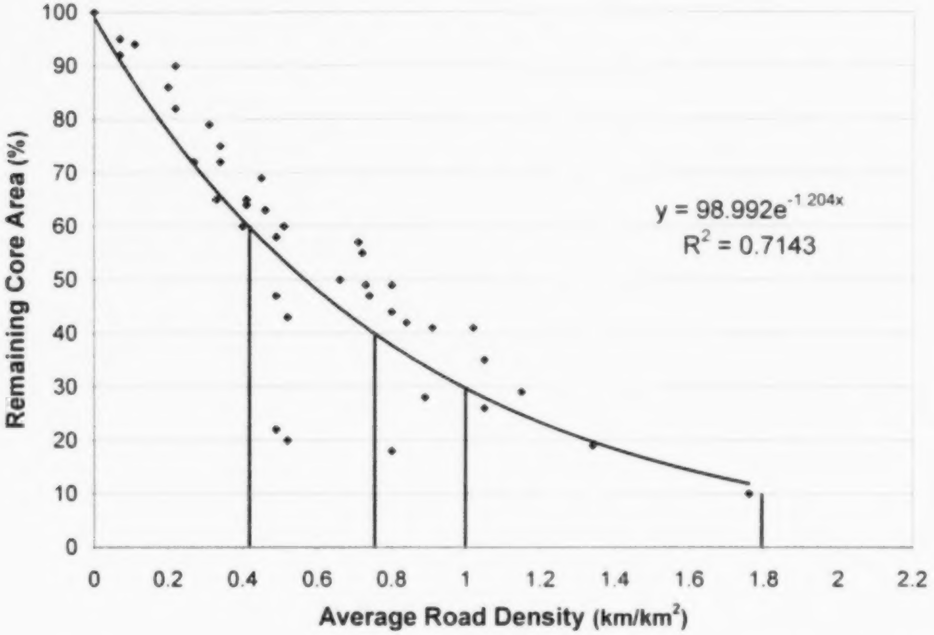


Figure 32 Relationship between road and trail density and remaining core area in the Sukunka Case Study area.

Although road and trail density appears to be a practical cumulative effects indicator, the Sukunka Case Study also demonstrates that documented relationships between road density and large wildlife species may not be directly applicable to northeast British Columbia. Animal response to habitat and disturbance features such as roads can be considered at two scales of analysis. At the regional scale, individuals or groups select home ranges or territories that meet all their life history need (2nd order selection). Within this home range or territory, individuals and groups select or avoid areas based on site-specific features (3rd order selection; Rettie and Messier 2000; Apps et al., 2001;

Szkorupa 2002). For example, wolf packs appear to select areas with low road densities and low densities of humans in populated landscapes. In many remote areas however, wolves appear to select areas close to roads, trails, and seismic lines. This suggests that it is not the physical feature the road represents that wolves avoid, but the positive correlation between road density and number of encounters with humans (reviewed in Whittington 2002). Prey species, including moose, caribou, and elk, appear to respond to disturbance in the opposite manner (Dyer 1999; Schneider and Wasel 2000), presumably to reduce the risk of wolf predation.

In addition, as noted in Appendix 1 (Section 2.3.4), physiological and behavioural responses of individuals may not be translated into reductions in animal numbers, particularly for species with high reproductive rates, species able to habituate to repeated disturbance (e.g., elk), or populations adjacent to protected or wilderness areas. For example, established models (Section 2.3.3, Appendix 1) predict that elk habitat effectiveness in the Sukunka study areas has been reduced by 15% to 50% due to construction of roads and trails (Section 3.3.4 in this report). Realized reductions in habitat effectiveness have not affected local populations, however, as the expansion of the road and trail network has coincided with a dramatic increase in elk populations in these areas. O'Neill (1993) also concluded that loss in habitat effectiveness is not a significant issue for many species in this region.

Another issue relates to the way in which road or access density indicators are calculated. Most documented road density relationships and thresholds are based on average (mean) values. The average value is a measure of central tendency and is most applicable to samples with a symmetrical or normal (e.g., bell curve) distribution. When samples are asymmetrical or skewed however, calculated average road density is greatly influenced by extremely high values. In these cases, the median (middle measurement) is the preferred method to describe central tendency (Zar 1984).

Figure 32 presents access density values calculated for 1 km^2 'cells' in the Sukunka Case Study area. Because road and trail curves are skewed to the left, calculated average road and trail densities are much larger than calculated median densities. This discrepancy is greatest at earlier stages of fragmentation, as observed in the Sukunka area. In addition, moving window analyses are particularly sensitive to boundary effects (Ake 1995), which can further bias average values. As linear features and associated fragmentation increase, the frequency distribution becomes more symmetrical. This was observed in the Blueberry Case Study (Appendix 2), but not the Sukunka Case Study, which is much less fragmented.

In the Blueberry Case Study, median road and trail density was the indicator that best predicted moose harvest, and was a better predictor than average density. No significant relationship was evident in the Sukunka Case Study area, possibly because the landscape was less fragmented. However, based on the access density frequency distribution calculated for the Sukunka Case Study area, use of median access density is considered to be more appropriate in forested areas of northeast British Columbia although average access density is the normal reporting convention.

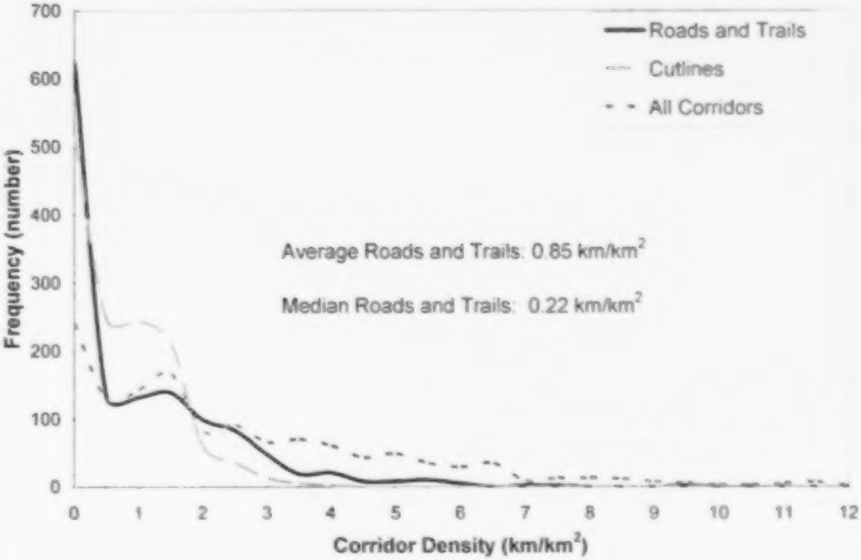


Figure 33. Current linear feature frequency in the Sukunka Case Study area.

4.1.2 Stream Crossing Index

Stream crossing indices were calculated for all subwatersheds in the Sukunka Case Study areas using TRIM II hydrography. Stream crossing indices for these areas were very low relative to other foothills areas (Alliance 1997; Salmo 1999, 2000, unpub. data). The TRIM II hydrography layer used for these analyses appears to overestimate the actual length of stream in each subwatershed, and thereby underestimates stream crossing frequency.

A comparative analysis undertaken in the Blueberry Case Study area using readily available 1:50,000 scale digital hydrography data indicates that smaller scale hydrography data are most appropriate for this indicator (Appendix 2).

4.1.3 Core Area

Remaining core area is considered to be one of the most practical cumulative effects indicators and has been widely used for grizzly bear and other species (reviewed in Section 4.1.4 of Appendix 1). This habitat index provides a useful complement to access density by identifying the availability and location of areas where minimal human impacts have occurred. In fragmented landscapes, these areas have increased importance for population persistence. Application of a minimum core area indicator can therefore be applied to help minimize further fragmentation.

In the Sukunka Case Study area, loss of core area occurred at a much higher rate than did clearing, reflecting the non-linear nature of edge effects (Figure 34). In the Sukunka area, the rate of core area loss was approximately exponential between 1969 and 1981, and has since slowed. Theoretical fragmentation models have identified critical changes at around 40% to 60% core area for habitat specialists such as woodland caribou and interior forest songbirds, and fragmentation in much of the Sukunka Case Study area has reached this critical range.

A generally accepted cumulative effects method has been developed to calculate core security areas for grizzly bear (e.g., Gibeau et al. 1996, Appendix 1). This method requires information on seasonal habitat suitability, disturbance features, and assumed or actual human use of these features on a seasonal basis. This method has recently begun to be applied to a variety of other large mammals, including moose. In the Sukunka Case Studies, there was no difference in the predictive power of generalized core area availability and an indicator that integrated habitat suitability. This suggests that generalized core area availability may be an alternative landscape indicator for tolerant habitat generalists such as moose and elk. More detailed, species-specific evaluations will be required for intolerant or sensitive species, such as woodland caribou, that rely on relatively large and isolated patches of suitable habitat for persistence.

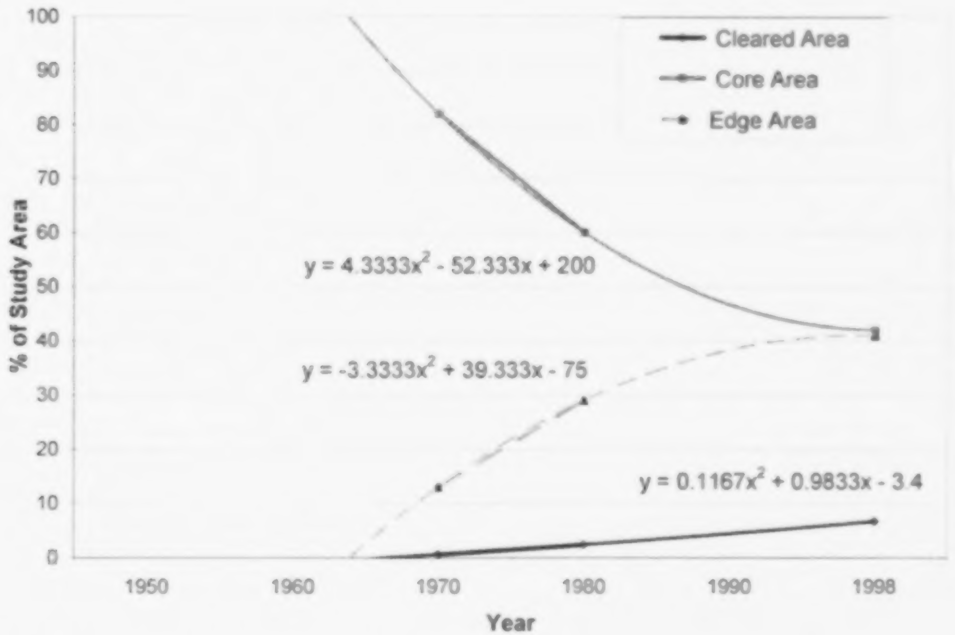


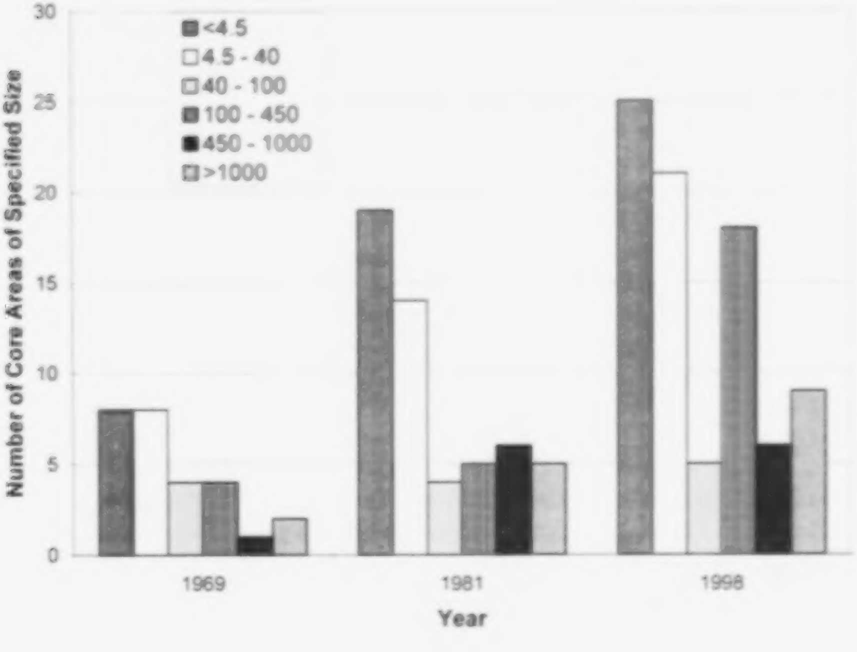
Figure 34. Trends in clearing, edge and core in the Sukunka Case Study area.

4.1.4 Patch and Corridor Size

Insufficient data on species abundance and distribution were available to test effects of patch and corridor size. In the Sukunka Case Study area, core areas changed from a few very large contiguous patches to a many fragments over the 30 to 50 year analysis period. Smaller fragments provide limited security for large or intolerant species, so patch and corridor size should be integrated into core area analyses to quantify those areas with value for focus species.

Figure 35 displays the change in calculated core area size for the Sukunka Case Study area between 1969 and the present. In 1969, most core area was included in a several very large, contiguous patches. Since that time, core area has been fragmented into smaller patches. Smaller fragments (<100 ha) provide limited security for large or intolerant species such as ovenbird (*Seiurus aurocapillus*), marten, grizzly bear, and wolverine. Very small fragments (<4.5 ha) provide limited security for small intolerant species, including most interior forest songbirds (reviewed in Section 4.1 of Appendix 1).

Figure 35. Core area size distribution in the Sukunka Case Study area.



4.1.5 Utility of Existing Data

The Case Studies also evaluated the utility of readily available data for use in cumulative effects models and assessments. For reasons summarized below, the availability and quality of existing data affected study conclusions.

The readily available TRIM II digital data provided to be insufficient to accurately identify disturbance features. Most significantly, many clearings are not identified, so it is impossible to distinguish industrial, commercial, and recreational facilities from forest cutblocks, houses, and agricultural fields. In addition, information on the age of the feature, reclamation status, and intensity of use is not available; this is critical for differentiating between high-use and low- or no-use features.

Existing forest cover data available from the British Columbia Provincial Government are known to be inaccurate and do not include insufficient information to develop reliable habitat suitability ratings. The Provincial Government is currently developing wildlife habitat maps based on the 1:250,000 Broad Terrestrial Ecosystem Classification scheme (BEI; RIC 1998) that are designed to be more suitable for cumulative effects analyses. In addition, medium to large scale Terrestrial Ecosystem Mapping (TEM; RIC 1999) is available for some areas. Use of these maps would enhance the consistency and accuracy of habitat suitability ratings and also reduce the cost to those evaluating cumulative effects.

Analyses of watershed indicators are sensitive to the scale of the hydrography layer used. The readily available TRIM II digital data includes numerous computer-generated watercourses that do not occur in the field. This causes critical stream-length based indicators (riparian area cleared, stream crossing index) to be inaccurate. For this reason, watershed indicators should be calculated using the 1:50,000 watershed polygons and stream network provided in the British Columbia Watershed Atlas.

Finally, the evaluation of relationships between development and renewable resource trends was primarily hindered by the lack of data on species abundance and distribution.

5. REFERENCES

5.1 PERSONAL COMMUNICATIONS

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APPENDIX A.

TERRESTRIAL AND AQUATIC DISTURBANCE FEATURES: 1969, 1981, CURRENT

1969 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km^2)	(ha)	(% of area)[10]
Sukunka Study Area																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.08	0.00	2.78	190.4	0.2	8968.2	7.4							0.03	0.021	8.3	0.1
Truck Trails	0.15	0.00	7.46	135.3	0.1	5369.3	4.4							0.05	0.036	6.9	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.04	0.00	5.69	50.9	0.0	755.0	0.6							0.01		7.3	0.1
Cutlines	0.08	0.00	2.81	79.9	0.1	0.0	0.0							0.04		4.4	0.0
Wellsites				1.7	0.0	3.7	0.0									0.0	0.0
Clearings				246.9	0.2	364.2	0.3									19.9	0.2
Existing Total	**0.22[7]**	**0.00[7]**	**7.46[7]**	**705**	**0.6**	**15461**	**13**	**99405**	**82**	**27**	**3681.7**	**0.8**	**95433**	**0.12[8]**	**0.057[9]**	**46.95**	**0.5**
Burnt River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.07	0.00	2.78	132.3	0.1	6799.4	6.2							0.02	0.015	6.2	
Truck Trails	0.13	0.00	5.39	102.3	0.1	4032.0	3.7							0.04	0.030	6.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.01	0.00	1.64	0.0	0.0	7.2	0.0							0.00		0.0	
Cutlines	0.08	0.00	2.81	73.4	0.1	0.0	0.0							0.04		4.2	
Wellsites				1.7	0.0	3.7	0.0									0.0	
Clearings				190.1	0.2	273.5	0.2									17.1	
Existing Total	**0.20[7]**	**0.00[7]**	**5.39[7]**	**500**	**0.5**	**11116**	**10**	**94182**	**86**	**12**	**7848.5**	**0.0**	**92268**	**0.10[8]**	**0.045[9]**	**33.50**	
Pine-Hasler RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.19	0.00	1.97	1.4	0.2	46.8	8.0							0.00	0.008	0.0	
Truck Trails	0.03	0.00	0.72	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.07	0.00	1.58	0.5	0.1	5.7	1.0							0.00		0.3	
Cutlines	0.02	0.00	0.51	0.0	0.0	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.22[7]**	**0.00[7]**	**1.97[7]**	**2**	**0.3**	**53**	**9**	**527**	**90**	**2**	**263.6**	**48.6**	**479**	**0.00[8]**	**0.008[9]**	**0.30**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1969 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area [1]		Total Edge Area [2]		Core Areas [3]						Stream Crossings	Valley Roads [5]	Riparian Area Cleared [6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area) [4]	(ha)	(% of area) [4]	ha	(% of area) [4]			min	max	(#/km)	(km/km²)	(ha)	(% of area) [10]
Sukunka Falls RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Truck Trails	0.52	0.00	2.28	1.6	0.8	89.3	41.3							0.00	0.163	0.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.12	0.00	0.84	0.3	0.1	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.52 [7]**	**0.00 [7]**	**2.28 [7]**	**2**	**0.9**	**89**	**41**	**93**	**43**	**2**	**46.6**	**17.2**	**76**	**0.00 [8]**	**0.163 [9]**	**0.00**	
Misc RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.33	0.00	2.77	21.3	0.7	896.7	29.5							0.14	0.116	1.0	
Truck Trails	0.16	0.00	2.79	2.9	0.1	86.8	2.9							0.02	0.011	0.1	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.10	0.00	1.58	10.2	0.3	155.0	5.1							0.05		1.8	
Cutlines	0.06	0.00	1.21	1.7	0.1	0.0	0.0							0.05		0.1	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				48.2	1.6	61.1	2.0									2.2	
Existing Total	**0.49 [7]**	**0.00 [7]**	**4.15 [7]**	**84**	**2.8**	**1200**	**39**	**1427**	**47**	**15**	**95.1**	**0.4**	**329**	**0.25 [8]**	**0.127 [9]**	**5.12**	
Sukunka River West Bank RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.21	0.00	2.78	27.2	0.5	1017.8	18.7							0.10	0.080	1.0	
Truck Trails	0.45	0.00	7.46	22.6	0.4	944.0	17.3							0.18	0.143	0.7	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.09	0.00	1.63	3.5	0.1	0.0	0.0							0.03		0.1	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	10.4	0.2									0.0	
Existing Total	**0.66 [7]**	**0.00 [7]**	**7.46 [7]**	**53**	**1.0**	**1972**	**36**	**2712**	**50**	**23**	**117.9**	**0.2**	**800**	**0.29 [8]**	**0.223 [9]**	**1.77**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities, a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1969 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km^2)	(ha)	(% of area)[10]
West Pine River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.14	0.00	2.57	8.2	0.4	207.5	9.9							0.02	0.072	0.2	
Truck Trails	0.35	0.00	5.39	6.0	0.3	217.3	10.3							0.11	0.065	0.2	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.90	0.00	5.69	40.3	1.9	587.1	27.9							0.73		5.2	
Cutlines	0.04	0.00	1.04	0.9	0.0	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				8.6	0.4	19.3	0.9									0.6	
Existing Total	**0.49[7]**	**0.00[7]**	**5.39[7]**	**64**	**3.0**	**1031**	**49**	**462**	**22**	**13**	**35.6**	**0.9**	**157**	**0.86[8]**	**0.137[9]**	**6.25**	
Falling Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.17	0.00	2.77	61.5	0.4	2391.9	16.1							0.07	0.062	2.8	0.2
Truck Trails	0.16	0.00	5.39	24.8	0.2	774.6	5.2							0.10	0.076	2.3	0.2
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.22	0.00	5.69	39.2	0.3	617.7	4.2							0.07		5.9	0.4
Cutlines	0.11	0.00	1.96	14.9	0.1	0.0	0.0							0.05		0.6	0.0
Wellsites				1.7	0.0	3.7	0.0									0.0	0.0
Clearings				131.3	0.9	112.3	0.8									13.8	1.0
Existing Total	**0.33[7]**	**0.00[7]**	**5.39[7]**	**273**	**1.8**	**3900**	**26**	**9596**	**65**	**18**	**533.1**	**0.2**	**8401**	**0.28[8]**	**0.139[9]**	**25.56**	**1.9**
Hasler Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.06	0.00	2.77	30.5	0.1	1601.8	6.2							0.02	0.014	1.6	0.1
Truck Trails	0.02	0.00	0.87	3.7	0.0	83.8	0.3							0.00	0.003	0.3	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.04	0.00	3.23	9.9	0.0	137.3	0.5							0.01		1.4	0.1
Cutlines	0.03	0.00	1.41	6.6	0.0	0.0	0.0							0.02		0.5	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				1.4	0.0	3.7	0.0									0.0	0.0
Existing Total	**0.07[7]**	**0.00[7]**	**2.77[7]**	**52**	**0.2**	**1827**	**7**	**23574**	**92**	**2**	**11786.9**	**4.6**	**23569**	**0.05[8]**	**0.017[P170]**	**3.80**	**0.2**

1 Area occupied by disturbance feature (roads and utility corridors 20 m wide; cutlines and truck trails 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area

1969 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Pine River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.17	0.00	2.77	38.7	0.3	1472.4	13.2							0.08	0.056	1.8	0.2
Truck Trails	0.14	0.00	2.79	12.1	0.1	260.8	2.3							0.04	0.037	0.5	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.01	0.00	1.08	1.8	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.02	0.00	1.20	1.5	0.0	0.0	0.0							0.01		0.1	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				73.1	0.7	85.8	0.8									2.3	0.3
Existing Total	**0.31[7]**	**0.00[7]**	**4.63[7]**	**127**	**1.1**	**1819**	**16**	**8790**	**79**	**7**	**1255.7**	**0.8**	**7359**	**0.13[8]**	**0.094[9]**	**4.71**	**0.6**
Highhat River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.07	0.00	2.78	59.0	0.2	3323.3	9.3							0.02	0.018	2.1	0.1
Truck Trails	0.27	0.00	7.46	72.1	0.2	3167.3	8.9							0.09	0.064	3.3	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.14	0.00	2.81	42.5	0.1	0.0	0.0							0.07		2.2	0.1
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				41.0	0.1	162.1	0.5									3.8	0.1
Existing Total	**0.34[7]**	**0.00[7]**	**7.46[7]**	**215**	**0.6**	**6653**	**19**	**25620**	**72**	**15**	**1708.0**	**0.9**	**23961**	**0.17[8]**	**0.082[9]**	**11.45**	**0.4**
Brazion Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.01	0.00	0.87	0.6	0.0	127.1	1.0							0.00	0.000	0.0	0.0
Truck Trails	0.07	0.00	4.12	6.5	0.0	252.8	1.9							0.02	0.015	0.2	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.09	0.00	1.56	11.6	0.1	0.0	0.0							0.05		0.9	0.1
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.1	0.0	0.4	0.0									0.0	0.0
Existing Total	**0.07[7]**	**0.00[7]**	**4.12[7]**	**19**	**0.1**	**380**	**3**	**12430**	**95**	**4**	**3107.4**	**1.2**	**12342**	**0.07[8]**	**0.015[9]**	**1.09**	**0.1**

[1] Area occupied by disturbance feature (roads and utility corridors: 20 m wide, cutlines and truck trails: 8 m wide; other features as calculated)

[2] Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

[3] Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

[4] Percent (%) of specified area, excluding lakes.

[5] Includes linear features within 100 m of a stream.

[6] Includes all cleared areas within 15 m of a waterbody.

[7] Total corridor density includes roads and truck trails.

[8] Total stream crossings include roads, truck trails, pipelines, and cutlines.

[9] Total valley roads include roads and truck trails.

[10] Percent of total riparian area.

1969 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²) min	Range (km/km²) max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	Total ha	Total (% of area)[4]	No.	Average Size (ha)	Range (ha) min	Range (ha) max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Burnt River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Truck Trails	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.00[7]**	**0.00[7]**	**0.00[7]**	**0**	**0.0**	**0**	**0**	**8946**	**100**	**2**	**4473.1**	**0.0**	**8946**	**0.00[8]**	**0.000[9]**	**0.00**	**0.0**
Brazion-Burnt Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.00	0.00	0.24	0.2	0.0	51.6	1.0							0.00	0.000	0.0	0.0
Truck Trails	0.30	0.00	2.48	12.6	0.2	640.2	12.2							0.07	0.041	0.3	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.02	0.00	1.17	0.5	0.0	0.0	0.0							0.00		0.0	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.31[7]**	**0.00[7]**	**2.48[7]**	**13**	**0.3**	**692**	**13**	**4132**	**79**	**3**	**1377.4**	**0.2**	**4110**	**0.07[8]**	**0.041[9]**	**0.28**	**0.1**
Rocky Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Truck Trails	0.11	0.00	2.07	3.5	0.1	189.9	2.8							0.00	0.000	0.0	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.04	0.00	1.17	2.3	0.0	0.0	0.0							0.01		0.1	0.0
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.11[7]**	**0.00[7]**	**2.07[7]**	**6**	**0.1**	**190**	**3**	**6317**	**94**	**2**	**3158.6**	**0.9**	**6316**	**0.01[8]**	**0.000[9]**	**0.06**	**0.0**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities, a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1981 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km^2)	(ha)	(% of area)[10]
Sukunka Study Area																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.29	0.00	7.64	710.2	0.6	24112.2	19.9							0.10	0.078	30.9	0.3
Truck Trails	0.21	0.00	9.14	194.7	0.2	7926.4	6.5							0.07	0.050	10.5	0.1
Pipelines	0.03	0.00	1.90	62.6	0.1	535.9	0.4							0.01		2.5	0.0
Railway Lines	0.04	0.00	5.69	50.7	0.0	663.8	0.5							0.01		7.3	0.1
Cutlines	0.36	0.00	3.78	363.3	0.3	0.0	0.0							0.18		20.3	0.2
Wellsites				18.7	0.0	58.6	0.0									0.1	0.0
Clearings				1471.3	1.2	1368.3	1.1									91.7	0.9
Existing Total	**0.51[7]**	**0.00[7]**	**9.48[7]**	**2871**	**2.4**	**34665**	**29**	**73229**	**60**	**52**	**1408.3**	**0.0**	**32800**	**0.37[8]**	**0.127[9]**	**163.39**	**1.6**
Burnt River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.27	0.00	5.56	594.9	0.5	21044.9	19.1							0.10	0.069	26.5	
Truck Trails	0.18	0.00	5.39	152.7	0.1	6464.2	5.9							0.06	0.042	9.1	
Pipelines	0.03	0.00	1.90	40.3	0.0	396.0	0.4							0.01		1.7	
Railway Lines	0.01	0.00	1.64	0.0	0.0	7.2	0.0							0.00		0.0	
Cutlines	0.38	0.00	3.11	342.1	0.3	0.0	0.0							0.19		19.6	
Wellsites				18.7	0.0	58.6	0.1									0.1	
Clearings				1208.2	1.1	1211.5	1.1									80.2	
Existing Total	**0.46[7]**	**0.00[7]**	**5.56[7]**	**2357**	**2.1**	**29182**	**27**	**69518**	**63**	**33**	**2106.6**	**0.1**	**32073**	**0.35[8]**	**0.111[9]**	**137.23**	
Pine-Hasler RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.36	0.00	3.43	2.6	0.4	86.8	14.8							0.08	0.070	0.1	
Truck Trails	0.09	0.00	0.75	0.1	0.0	16.4	2.8							0.00	0.000	0.0	
Pipelines	0.12	0.00	1.27	1.0	0.2	0.0	0.0							0.08		0.1	
Railway Lines	0.07	0.00	1.58	0.5	0.1	5.7	1.0							0.00		0.3	
Cutlines	0.37	0.00	1.89	1.0	0.2	0.0	0.0							0.08		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.5	0.1									0.0	
Existing Total	**0.45[7]**	**0.00[7]**	**3.43[7]**	**5**	**0.9**	**109**	**19**	**405**	**69**	**3**	**135.0**	**48.6**	**299**	**0.25[8]**	**0.070[9]**	**0.48**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails 8 m wide, other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream

6 Includes all cleared areas within 15 m of a waterbody

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines

9 Total valley roads include roads and truck trails

10 Percent of total riparian area

1981 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No.	Average Size (ha)	Range (ha)					
		min.	max.	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min.	max.	(#/km)	(km/km^2)	(ha)	(% of area)[10]
Sukunka Falls RMZ																	
Primary Road	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Truck Trails	0.52	0.00	2.28	1.6	0.8	89.3	41.3							0.00	0.163	0.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.14	0.00	0.84	0.3	0.1	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.52[7]**	**0.00[7]**	**2.28[7]**	**2**	**0.9**	**89**	**41**	**93**	**43**	**2**	**46.6**	**17.2**	**76**	**0.00[8]**	**0.163[9]**	**0.00**	
Misc RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.90	0.00	7.64	61.7	2.0	1334.6	43.9							0.30	0.336	2.8	
Truck Trails	0.44	0.00	9.14	8.7	0.3	159.6	5.3							0.18	0.130	0.4	
Pipelines	0.16	0.00	1.40	14.9	0.5	120.1	4.0							0.07		0.4	
Railway Lines	0.10	0.00	1.58	10.0	0.3	69.5	2.3							0.05		1.8	
Cutlines	0.20	0.00	1.58	4.9	0.2	0.0	0.0							0.11		0.2	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				254.5	8.4	130.9	4.3									10.9	
Existing Total	**1.34[7]**	**0.00[7]**	**9.48[7]**	**355**	**11.7**	**1815**	**60**	**575**	**19**	**12**	**47.9**	**0.1**	**203**	**0.69[8]**	**0.466[9]**	**16.48**	
Sukunka River West Bank RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.36	0.00	6.58	40.1	0.7	1377.2	25.3							0.12	0.102	1.3	
Truck Trails	0.56	0.00	7.46	25.6	0.5	979.6	18.0							0.20	0.159	0.8	
Pipelines	0.01	0.00	1.14	1.8	0.0	15.5	0.3							0.01		0.1	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.33	0.00	3.78	13.0	0.2	0.0	0.0							0.11		0.4	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	6.3	0.1									0.0	
Existing Total	**0.91[7]**	**0.00[7]**	**7.46[7]**	**80**	**1.5**	**2379**	**44**	**2227**	**41**	**25**	**89.1**	**0.0**	**455**	**0.41[8]**	**0.261[9]**	**2.59**	

1 Area occupied by disturbance feature (roads and utility corridors 20 m wide, cutlines and truck trails 8 m wide; other features as calculated)
2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.
3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines
4 Percent (%) of specified area, excluding lakes
5 Includes linear features within 100 m of a stream
6 Includes all cleared areas within 15 m of a waterbody
7 Total corridor density includes roads and truck trails
8 Total stream crossings include roads, truck trails, pipelines, and cutlines
9 Total valley roads include roads and truck trails
10 Percent of total riparian area

1981 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
West Pine River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.17	0.00	2.91	10.9	0.5	268.7	12.8							0.04	0.084	0.3	
Truck Trails	0.35	0.00	5.39	6.0	0.3	217.3	10.3							0.11	0.065	0.2	
Pipelines	0.14	0.00	1.90	4.5	0.2	4.2	0.2							0.06		0.3	
Railway Lines	0.90	0.00	5.69	40.2	1.9	581.3	27.6							0.73		5.2	
Cutlines	0.09	0.00	1.38	2.0	0.1	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				8.6	0.4	19.3	0.9									0.6	
Existing Total	**0.52[7]**	**0.00[7]**	**5.39[7]**	**72**	**3.4**	**1091**	**52**	**411**	**20**	**12**	**34.3**	**0.9**	**157**	**0.93[8]**	**0.149[9]**	**6.62**	
Falling Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.22	0.00	4.46	71.5	0.5	2693.2	18.1							0.08	0.070	3.8	0.3
Truck Trails	0.18	0.00	5.39	26.2	0.2	884.6	6.0							0.10	0.076	2.3	0.2
Pipelines	0.05	0.00	1.90	8.4	0.1	94.2	0.6							0.01		0.5	0.0
Railway Lines	0.22	0.00	5.69	39.0	0.3	552.1	3.7							0.07		5.9	0.4
Cutlines	0.25	0.00	3.00	29.5	0.2	0.0	0.0							0.11		1.7	0.1
Wellsites				1.7	0.0	3.7	0.0									0.0	0.0
Clearings				131.5	0.9	136.4	0.9									13.8	1.0
Existing Total	**0.40[7]**	**0.00[7]**	**5.39[7]**	**308**	**2.1**	**4364**	**29**	**8897**	**60**	**16**	**556.0**	**0.3**	**5675**	**0.36[8]**	**0.147[9]**	**28.05**	**2.1**
Hasler Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.42	0.00	5.56	247.8	1.0	6939.4	26.9							0.16	0.115	9.8	0.4
Truck Trails	0.07	0.00	1.25	12.2	0.0	681.5	2.6							0.02	0.015	1.6	0.1
Pipelines	0.05	0.00	1.35	18.0	0.1	69.8	0.3							0.01		0.2	0.0
Railway Lines	0.04	0.00	3.23	9.9	0.0	111.7	0.4							0.01		1.4	0.1
Cutlines	0.38	0.00	3.00	76.8	0.3	0.0	0.0							0.18		4.3	0.2
Wellsites				3.1	0.0	0.0	0.0									0.0	0.0
Clearings				645.1	2.5	184.8	0.7									40.3	1.6
Existing Total	**0.49[7]**	**0.00[7]**	**5.56[7]**	**1013**	**3.9**	**7987**	**31**	**15061**	**58**	**8**	**1882.6**	**1.3**	**8499**	**0.38[8]**	**0.130[9]**	**57.65**	**2.4**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines

4 Percent (%) of specified area, excluding lakes

5 Includes linear features within 100 m of a stream

6 Includes all cleared areas within 15 m of a waterbody

7 Total corridor density includes roads and truck trails

8 Total stream crossings include roads, truck trails, pipelines, and cutlines

9 Total valley roads include roads and truck trails

10 Percent of total riparian area

1981 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area [1]		Total Edge Area [2]		Core Areas [3]						Stream Crossings	Valley Roads [5]	Riparian Area Cleared [6]	
	Average (km/km²)	Range (km/km²) min.	Range (km/km²) max.	(ha)	(% of area) [4]	(ha)	(% of area) [4]	Total ha	Total (% of area) [4]	No	Average Size (ha)	Range (ha) min	Range (ha) max	(#/km)	(km/km²)	(ha)	(% of area) [10]
Pine River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.42	0.00	6.58	83.7	0.8	2743.5	24.7							0.15	0.112	3.6	0.5
Truck Trails	0.31	0.00	9.14	22.9	0.2	757.7	6.8							0.11	0.082	1.1	0.2
Pipelines	0.02	0.00	1.35	3.5	0.0	4.9	0.0							0.00		0.1	0.0
Railway Lines	0.01	0.00	1.08	1.8	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.44	0.00	2.42	43.9	0.4	0.0	0.0							0.23		2.0	0.3
Wellsites				2.7	0.0	5.4	0.0									0.0	0.0
Clearings				252.4	2.3	134.4	1.2									10.0	1.4
Existing Total	**0.72 [7]**	**0.00 [7]**	**9.14 [7]**	**411**	**3.7**	**3646**	**33**	**6061**	**55**	**9**	**673.5**	**0.1**	**4811**	**0.49 [8]**	**0.194 [9]**	**16.76**	**2.3**
Highhat River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.38	0.00	7.64	255.0	0.7	9322.2	26.1							0.12	0.094	10.6	0.4
Truck Trails	0.35	0.00	7.46	96.1	0.3	3856.7	10.8							0.10	0.077	3.9	0.1
Pipelines	0.04	0.00	1.19	24.5	0.1	250.1	0.7							0.02		1.4	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.48	0.00	3.78	138.9	0.4	0.0	0.0							0.23		7.5	0.3
Wellsites				10.1	0.0	39.3	0.1									0.1	0.0
Clearings				334.4	0.9	337.5	0.9									18.7	0.6
Existing Total	**0.74 [7]**	**0.00 [7]**	**9.48 [7]**	**859**	**2.4**	**13806**	**39**	**16601**	**47**	**34**	**488.3**	**0.0**	**9656**	**0.46 [8]**	**0.171 [9]**	**42.11**	**1.5**
Brazion Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.20	0.00	4.92	38.1	0.3	1816.1	13.9							0.08	0.050	2.7	0.2
Truck Trails	0.08	0.00	4.12	6.8	0.1	260.8	2.0							0.02	0.016	0.3	0.0
Pipelines	0.03	0.00	1.13	8.2	0.1	117.0	0.9							0.01		0.3	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.35	0.00	2.19	39.1	0.3	0.0	0.0							0.19		3.2	0.2
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				34.4	0.3	411.8	3.2									6.2	0.4
Existing Total	**0.27 [7]**	**0.00 [7]**	**4.92 [7]**	**127**	**1.0**	**2606**	**20**	**9420**	**72**	**10**	**942.0**	**0.7**	**8970**	**0.30 [8]**	**0.066 [9]**	**12.77**	**0.9**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1981 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area [1]		Total Edge Area [2]		Core Areas [3]						Stream Crossings	Valley Roads [5]	Riparian Area Cleared [6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area) [4]	(ha)	(% of area) [4]	ha	(% of area) [4]			min	max	(#/km)	(km/km²)	(ha)	(% of area) [10]
Burnt River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Truck Trails	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.09	0.00	1.77	6.6	0.1	0.0	0.0							0.08		0.5	0.1
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				0.0	0.0	0.0	0.0									0.0	0.0
Existing Total	**0.00 [7]**	**0.00 [7]**	**0.00 [7]**	**7**	**0.1**	**0**	**0**	**8946**	**100**	**2**	**4473.1**	**0.0**	**8946**	**0.08 [8]**	**0.000 [9]**	**0.47**	**0.1**
Brazion-Burnt Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.03	0.00	2.24	0.2	0.0	50.5	1.0							0.00	0.000	0.0	0.0
Truck Trails	0.30	0.00	2.48	12.6	0.2	633.8	12.0							0.07	0.041	0.3	0.1
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.20	0.00	1.77	8.6	0.2	0.0	0.0							0.06		0.3	0.1
Wellsites				1.0	0.0	10.2	0.2									0.0	0.0
Clearings				15.6	0.3	58.2	1.1									0.0	0.0
Existing Total	**0.34 [7]**	**0.00 [7]**	**2.48 [7]**	**38**	**0.7**	**753**	**14**	**3974**	**75**	**3**	**1324.6**	**0.2**	**3952**	**0.13 [8]**	**0.041 [9]**	**0.55**	**0.1**
Rocky Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.08	0.00	3.74	14.0	0.2	547.5	8.2							0.04	0.026	0.5	0.1
Truck Trails	0.32	0.00	2.67	18.0	0.3	851.3	12.7							0.14	0.066	1.0	0.2
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.32	0.00	2.99	19.9	0.3	0.0	0.0							0.18		0.9	0.2
Wellsites				0.0	0.0	0.0	0.0									0.0	0.0
Clearings				58.0	0.9	105.2	1.6									2.7	0.5
Existing Total	**0.41 [7]**	**0.00 [7]**	**3.74 [7]**	**110**	**1.6**	**1504**	**22**	**4269**	**64**	**3**	**1423.2**	**0.1**	**4269**	**0.36 [8]**	**0.092 [9]**	**5.04**	**1.0**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines

4 Percent (%) of specified area, excluding lakes

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No	Average Size (ha)	Range (ha)					
		min.	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min.	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Sukunka Study Area																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.59	0.00	7.64	1431.9	1.2	37640.3	31.0							0.22	0.160	61.8	0.6
Truck Trails	0.26	0.00	9.14	231.6	0.2	7767.4	6.4							0.08	0.061	12.7	0.1
Pipelines	0.08	0.00	2.31	172.2	0.1	1555.7	1.3							0.04		8.9	0.1
Railway Lines	0.04	0.00	5.69	49.5	0.0	534.5	0.4							0.01		7.3	0.1
Cutlines	0.55	0.00	3.78	552.7	0.5	0.0	0.0							0.28		31.7	0.3
Wellsites				50.7	0.0	122.0	0.1									0.6	0.0
Clearings				5607.9	4.6	1811.8	1.5									339.9	3.3
Existing Total	**0.84[7]**	**0.00[7]**	**9.48[7]**	**8097**	**6.7**	**49432**	**41**	**51410**	**42**	**85**	**604.8**	**0.0**	**14182**	**0.61[8]**	**0.221[9]**	**462.95**	**4.4**
Burnt River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.58	0.00	6.67	1269.4	1.2	33590.9	30.6							0.22	0.156	56.2	
Truck Trails	0.22	0.00	5.39	182.3	0.2	6179.8	5.6							0.07	0.050	11.0	
Pipelines	0.08	0.00	2.31	148.3	0.1	1495.2	1.4							0.04		8.1	
Railway Lines	0.01	0.00	1.64	0.0	0.0	2.5	0.0							0.00		0.0	
Cutlines	0.59	0.00	3.53	520.0	0.5	0.0	0.0							0.29		30.6	
Wellsites				50.7	0.0	122.0	0.1									0.6	
Clearings				5178.9	4.7	1663.6	1.5									322.5	
Existing Total	**0.80[7]**	**0.00[7]**	**6.97[7]**	**7350**	**6.7**	**43054**	**39**	**48720**	**44**	**64**	**761.3**	**0.0**	**13933**	**0.60[8]**	**0.207[9]**	**428.96**	
Pine-Hasler RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.53	0.00	4.06	2.6	0.4	87.8	15.0							0.08	0.078	0.1	
Truck Trails	0.19	0.00	1.13	0.3	0.0	35.6	6.1							0.00	0.007	0.0	
Pipelines	0.12	0.00	1.27	1.0	0.2	0.0	0.0							0.08		0.1	
Railway Lines	0.07	0.00	1.58	0.5	0.1	5.1	0.9							0.00		0.3	
Cutlines	0.45	0.00	1.89	1.1	0.2	0.0	0.0							0.08		0.1	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.5	0.1									0.0	
Existing Total	**0.71[7]**	**0.00[7]**	**4.06[7]**	**6**	**0.9**	**129**	**22**	**334**	**57**	**3**	**111.2**	**48.2**	**228**	**0.28[8]**	**0.085[9]**	**0.48**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No.	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
Sukunka Falls RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Truck Trails	0.52	0.00	2.28	1.6	0.8	89.3	41.3							0.00	0.238	0.0	
Pipelines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.35	0.00	1.46	0.3	0.1	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				0.0	0.0	0.0	0.0									0.0	
Existing Total	**0.52**[7]	**0.00**[7]	**2.28**[7]	**2**	**0.9**	**89**	**41**	**93**	**43**	**2**	**46.6**	**17.2**	**76**	**0.00**[8]	**0.238**[9]	**0.00**	
Misc RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	1.18	0.00	7.64	88.0	2.9	1656.0	54.5							0.43	0.424	3.4	
Truck Trails	0.58	0.00	9.14	13.2	0.4	236.6	7.8							0.30	0.222	0.7	
Pipelines	0.16	0.00	1.40	14.7	0.5	29.3	1.0							0.07		0.3	
Railway Lines	0.10	0.00	1.58	9.1	0.3	1.5	0.0							0.05		1.8	
Cutlines	0.31	0.00	2.37	8.6	0.3	0.0	0.0							0.12		0.2	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				362.4	11.9	120.3	4.0									16.2	
Existing Total	**1.76**[7]	**0.00**[7]	**9.48**[7]	**496**	**16.3**	**2044**	**67**	**296**	**10**	**11**	**26.9**	**0.1**	**203**	**0.90**[8]	**0.646**[9]	**22.66**	
Sukunka River West Bank RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.52	0.00	6.58	55.2	1.0	1940.1	35.6							0.14	0.126	1.6	
Truck Trails	0.63	0.00	7.46	28.2	0.5	1008.8	18.5							0.21	0.176	0.8	
Pipelines	0.04	0.00	1.15	3.7	0.1	31.3	0.6							0.02		0.2	
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	
Cutlines	0.49	0.00	3.78	20.7	0.4	0.0	0.0							0.18		0.8	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				42.7	0.8	9.2	0.2									0.6	
Existing Total	**1.15**[7]	**0.00**[7]	**7.46**[7]	**150**	**2.8**	**2989**	**55**	**1580**	**29**	**27**	**58.5**	**0.0**	**238**	**0.53**[8]	**0.302**[9]	**3.97**	

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated)

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km²)	Range (km/km²)						Total		No.	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km²)	(ha)	(% of area)[10]
West Pine River RMZ																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	
Secondary Roads	0.44	0.00	3.89	16.7	0.8	365.6	17.4							0.09	0.124	0.5	
Truck Trails	0.35	0.00	5.39	6.0	0.3	217.3	10.3							0.11	0.065	0.2	
Pipelines	0.14	0.00	1.90	4.5	0.2	0.0	0.0							0.06		0.3	
Railway Lines	0.90	0.00	5.69	39.9	1.9	525.4	25.0							0.73		5.2	
Cutlines	0.11	0.00	1.38	2.0	0.1	0.0	0.0							0.00		0.0	
Wellsites				0.0	0.0	0.0	0.0									0.0	
Clearings				23.8	1.1	18.2	0.9									0.7	
Existing Total	**0.80[7]**	**0.00[7]**	**5.39[7]**	**93**	**4.4**	**1127**	**54**	**387**	**18**	**10**	**38.7**	**0.9**	**157**	**0.97[8]**	**0.189[9]**	**6.88**	
Falling Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.57	0.00	5.88	185.6	1.2	4035.0	27.2							0.17	0.162	7.7	0.6
Truck Trails	0.23	0.00	5.39	30.2	0.2	832.4	5.6							0.10	0.078	2.4	0.2
Pipelines	0.05	0.00	1.90	8.1	0.1	2.1	0.0							0.01		0.5	0.0
Railway Lines	0.22	0.00	5.69	37.9	0.3	465.8	3.1							0.07		5.8	0.4
Cutlines	0.38	0.00	3.00	42.9	0.3	0.0	0.0							0.18		2.8	0.2
Wellsites				1.7	0.0	3.7	0.0									0.0	0.0
Clearings				531.8	3.6	163.4	1.1									28.8	2.2
Existing Total	**0.80[7]**	**0.00[7]**	**6.97[7]**	**838**	**5.6**	**5502**	**37**	**7310**	**49**	**16**	**456.9**	**0.0**	**4713**	**0.52[8]**	**0.240[9]**	**48.04**	**3.6**
Hasler Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.61	0.00	5.56	337.7	1.3	7847.0	30.5							0.20	0.150	12.8	0.5
Truck Trails	0.11	0.00	2.69	20.3	0.1	897.9	3.5							0.03	0.025	2.5	0.1
Pipelines	0.05	0.00	1.35	17.7	0.1	53.6	0.2							0.01		0.2	0.0
Railway Lines	0.04	0.00	3.23	9.9	0.0	68.8	0.3							0.01		1.4	0.1
Cutlines	0.56	0.00	3.04	113.1	0.4	0.0	0.0							0.29		6.6	0.3
Wellsites				3.1	0.0	0.0	0.0									0.0	0.0
Clearings				1237.3	4.8	206.3	0.8									58.4	2.4
Existing Total	**0.73[7]**	**0.00[7]**	**5.62[7]**	**1739**	**6.8**	**9074**	**35**	**12578**	**49**	**12**	**1048.2**	**0.1**	**4694**	**0.53[8]**	**0.175[9]**	**81.93**	**3.4**

[1] Area occupied by disturbance feature (roads and utility corridors: 20 m wide, cutlines and truck trails: 8 m wide; other features as calculated).

[2] Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

[3] Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

[4] Percent (%) of specified area, excluding lakes.

[5] Includes linear features within 100 m of a stream.

[6] Includes all cleared areas within 15 m of a waterbody.

[7] Total corridor density includes roads and truck trails.

[8] Total stream crossings include roads, truck trails, pipelines, and cutlines.

[9] Total valley roads include roads and truck trails.

[10] Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No.	Average Size (ha)	Range (ha)					
		min	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km^2)	(ha)	(% of area)[10]
Pine River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.63	0.00	6.58	136.4	1.2	3464.0	31.1							0.30	0.188	6.2	0.8
Truck Trails	0.39	0.00	9.14	28.5	0.3	668.3	6.0							0.14	0.107	1.4	0.2
Pipelines	0.02	0.00	1.35	3.5	0.0	4.9	0.0							0.00		0.1	0.0
Railway Lines	0.01	0.00	1.08	1.8	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.47	0.00	2.42	45.8	0.4	0.0	0.0							0.23		1.9	0.3
Wellsites				2.7	0.0	4.1	0.0									0.0	0.0
Clearings				793.0	7.1	249.2	2.2									52.7	7.2
Existing Total	**1.02[7]**	**0.00[7]**	**9.14[7]**	**1012**	**9.1**	**4391**	**39**	**4575**	**41**	**10**	**457.5**	**1.1**	**3169**	**0.64[8]**	**0.295[9]**	**62.33**	**8.5**
Highhat River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.64	0.00	7.64	442.4	1.2	12079.5	33.9							0.22	0.165	17.7	0.6
Truck Trails	0.41	0.00	7.46	110.4	0.3	3810.2	10.7							0.12	0.094	4.8	0.2
Pipelines	0.07	0.00	1.44	38.0	0.1	337.3	0.9							0.03		2.2	0.1
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.63	0.00	3.78	183.4	0.5	0.0	0.0							0.32		10.5	0.4
Wellsites				11.8	0.0	39.0	0.1									0.1	0.0
Clearings				1782.4	5.0	229.9	0.6									100.4	3.5
Existing Total	**1.05[7]**	**0.00[7]**	**9.48[7]**	**2568**	**7.2**	**16496**	**46**	**12308**	**35**	**44**	**279.7**	**0.0**	**3442**	**0.67[8]**	**0.259[9]**	**135.78**	**4.7**
Brazion Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.43	0.00	5.77	104.0	0.8	3607.1	27.7							0.20	0.147	6.8	0.5
Truck Trails	0.10	0.00	4.12	9.3	0.1	340.4	2.6							0.03	0.023	0.4	0.0
Pipelines	0.18	0.00	1.41	52.9	0.4	707.5	5.4							0.09		3.3	0.2
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.67	0.00	3.22	66.8	0.5	0.0	0.0							0.33		5.4	0.4
Wellsites				8.0	0.1	5.7	0.0									0.0	0.0
Clearings				287.0	2.2	599.0	4.6									34.2	2.4
Existing Total	**0.52[7]**	**0.00[7]**	**5.77[7]**	**528**	**4.0**	**5260**	**40**	**5576**	**43**	**19**	**293.5**	**0.0**	**3397**	**0.62[8]**	**0.170[9]**	**50.07**	**3.5**

1 Area occupied by disturbance feature (roads and utility corridors: 20 m wide; cutlines and truck trails: 8 m wide; other features as calculated).

2 Edge Area estimated based on a 500 m buffer on either side of roads, wellsites, facilities, and communities; a 250 m buffer either side of truck trails, pipelines, railway lines and cutblocks/clearings. Cutlines are not buffered.

3 Core Areas represent areas greater than 500 m from all disturbance features, excluding cutlines.

4 Percent (%) of specified area, excluding lakes.

5 Includes linear features within 100 m of a stream.

6 Includes all cleared areas within 15 m of a waterbody.

7 Total corridor density includes roads and truck trails.

8 Total stream crossings include roads, truck trails, pipelines, and cutlines.

9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.

1998 Disturbance Features	Landscape Indicator																
	Corridor Density			Total Cleared Area[1]		Total Edge Area[2]		Core Areas[3]						Stream Crossings	Valley Roads[5]	Riparian Area Cleared[6]	
	Average (km/km^2)	Range (km/km^2)						Total		No	Average Size (ha)	Range (ha)					
		min.	max	(ha)	(% of area)[4]	(ha)	(% of area)[4]	ha	(% of area)[4]			min	max	(#/km)	(km/km^2)	(ha)	(% of area)[10]
Burnt River Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.41	0.00	3.72	55.0	0.6	1624.0	18.2							0.19	0.120	3.7	0.5
Truck Trails	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Pipelines	0.17	0.00	2.31	23.5	0.3	217.2	2.4							0.06		1.3	0.2
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.54	0.00	3.22	34.8	0.4	0.0	0.0							0.28		1.9	0.3
Wellsites				5.4	0.1	24.2	0.3									0.5	0.1
Clearings				356.2	4.0	193.4	2.2									32.3	4.5
Existing Total	**0.41[7]**	**0.00[7]**	**3.72[7]**	**475**	**5.3**	**2059**	**23**	**5852**	**65**	**6**	**975.3**	**0.0**	**2891**	**0.52[8]**	**0.120[9]**	**39.72**	**5.5**
Brazion-Burnt Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.59	0.00	3.40	71.7	1.4	2564.4	48.7							0.24	0.179	2.6	0.7
Truck Trails	0.31	0.00	2.48	12.6	0.2	419.8	8.0							0.07	0.046	0.3	0.1
Pipelines	0.16	0.00	1.21	17.5	0.3	39.9	0.8							0.09		0.7	0.2
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.65	0.00	2.66	24.9	0.5	0.0	0.0							0.20		1.0	0.2
Wellsites				11.6	0.2	14.5	0.3									0.0	0.0
Clearings				156.9	3.0	58.0	1.1									10.5	2.7
Existing Total	**0.89[7]**	**0.00[7]**	**3.63[7]**	**295**	**5.6**	**3097**	**59**	**1460**	**28**	**11**	**132.7**	**0.0**	**822**	**0.57[8]**	**0.225[9]**	**15.12**	**3.8**
Rocky Creek Watershed																	
Primary Roads	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00	0.000	0.0	0.0
Secondary Roads	0.69	0.00	6.67	99.0	1.5	2419.4	36.2							0.35	0.192	4.2	0.8
Truck Trails	0.36	0.00	2.67	20.2	0.3	798.4	11.9							0.15	0.072	1.0	0.2
Pipelines	0.09	0.00	1.29	10.9	0.2	193.4	2.9							0.05		0.6	0.1
Railway Lines	0.00	0.00	0.00	0.0	0.0	0.0	0.0							0.00		0.0	0.0
Cutlines	0.82	0.00	3.39	41.0	0.6	0.0	0.0							0.32		1.5	0.3
Wellsites				6.4	0.1	30.7	0.5									0.0	0.0
Clearings				463.4	6.9	112.6	1.7									22.6	4.6
Existing Total	**1.05[7]**	**0.00[7]**	**6.67[7]**	**641**	**9.6**	**3554**	**53**	**1751**	**26**	**11**	**159.1**	**0.0**	**731**	**0.85[8]**	**0.264[9]**	**29.96**	**6.0**

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9 Total valley roads include roads and truck trails.

10 Percent of total riparian area.